# Lake Connewarre Values Project

## Literature Review

P.G. Dahlhaus (compiler), C.A. Billows, S.P. Carey, J. Gwyther & E.L. Nathan

*December 2007*

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**Lake Connewarre Values Project**

*Project management*
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**Cover Photos:**
(upper left) Lower Barrage, Barwon River (photo by Peter Dahlhaus);
(middle right) Reedy Lake (photo by Peter Dahlhaus);
(lower centre) aerial view of Lake Connewarre (photo by Leigh Dennis).

# Executive Summary

The Lake Connewarre Complex consists broadly of Lake Connewarre, Reedy Lake, and Hospital and Salt swamps as well as associated sections of the lower Barwon River. The complex forms part of the Port Phillip Bay (Western Shoreline) and Bellarine Peninsula Ramsar Site.

This literature review has been commissioned by the Corangamite Catchment Management Authority as a component of the Connewarre Values Project. The project has been funded through the Victorian Water Trust – Healthy Rivers Initiative. The review is part of a larger investigation aimed at describing the existing biological, geomorphological and hydrological characteristics of the Lake Connewarre Complex, to better understand the complex issues which potentially impact the complex and to determine whether and what interventions may be required.

This report documents a review of the available published and unpublished documents from 1835 to 2007, relevant to the Lake Connewarre Complex. The review is focused on the areas of environmental history, geology, geomorphology, sedimentation, hydrogeology, terrestrial and aquatic floral communities, terrestrial and aquatic fauna, water quality and environmental flows. The report summarises the issues related to each topic which are considered relevant to the project aims. Additional research or investigations were not undertaken in this component of the project.

The review has shown that the Lake Connewarre Complex has significant attributes which make it valuable as a natural asset, as recognised by its Ramsar status. The value of the lake and environs to the local and regional communities has probably been understated in its recent management. It is apparent that many community groups such as the Field and Game Association and the Geelong Field Naturalists have made an extraordinary contribution to maintaining the values of the Lake Connewarre Complex. Universities (especially Deakin University) and state government agencies and authorities have made the most significant contributions to the research and investigations to date.

Overall, there are few studies which make a significant contribution to our understanding of contemporary processes and management issues in the Lake Connewarre Complex. In particular, there is a paucity of information on the interactions between the three hydrological systems – surface water, groundwater and marine waters. Very few data exist on water quality and sediment quality, and their relationship to ecosystem health. There has been relatively little information published about the biological components of the Lake Connewarre Complex compared with the geological components. The environmental history has been poorly documented compared to the social history, and should address the likely impacts of industrial, mining and urban development, in addition to river regulation and alterations to flow.

In geological terms, the Lake Connewarre Complex is a transient feature in a young and dynamic landscape. Over the past hundred thousand years, the landscape surrounding the complex has undergone vast changes due to massive variations in climate, river flows and sea levels. In the historical time frame, anthropogenic changes to land and water use over the past 170 years, especially during the first century of settlement at Geelong, have also resulted in landscape modifications. These have been at a smaller scale but accelerated rate when compared to the natural changes. The landscape of the Lake Connewarre Complex today continues to be modified by both natural and anthropogenic processes.

These processes threaten the values and environmental integrity of the Lake Connewarre Complex and have been summarised at the end of each section of the review, as well as condensed in the conclusions. It is of particular importance that the future management of the complex should be based on the integration of the landscape components (geology, geomorphology, hydrology, ecology) with cultural values. The predicted effects of climate change and the pressure this will impose on land and water use are of greatest concern.

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### Table of Abbreviations

| Abbreviation | Term in full |
|---|---|
| AVW | Atlas of Victorian Wildlife |
| AWSG | Australian Wader Study Group |
| BP | Before present |
| CMA | Catchment Management Authority |
| ENSO | El Niño – Southern Oscillation |
| EPBC Act | Environment Protection and Biodiversity Conservation Act |
| EVC | Ecological Vegetation Class |
| FFG Act | Flora and Fauna Guarantee Act |
| IPCC | Intergovernmental Panel on Climate Change |
| LCSGR | Lake Connewarre State Game Reserve |
| OBP | Orange-bellied parrot |
| PIRVic | Primary Industries Research Victoria |
| RAOU | Royal Australian Ornithologists Union |
| SKM | Sinclair Knight Mertz Pty Ltd |
| SRWSC | State Rivers and Water Supply Commission |
| VMU | Vegetation map unit |
| VROTs | Victorian rare or threatened species |

# 1 Introduction

This literature review has been commissioned by the Corangamite Catchment Management Authority (CMA) as a component of the Connewarre Values Project. The project has been funded through the Victorian Water Trust – Healthy Rivers Initiative and aims to:

1. Obtain a better understanding of the complex issues which potentially impact on the Lake Connewarre Complex;
2. Determine the extent to which these impacts occur; and
3. Determine whether and what interventions may be required.

The Connewarre Values Project consists of five sub-projects, of which this literature review is one.

## 1.1 Scope of this report

This report documents a review of the available published and unpublished documents relevant to the Lake Connewarre Complex. The review is focused on the areas of environmental history, geology, geomorphology, sedimentation, hydrogeology, terrestrial and aquatic floral communities, terrestrial and aquatic fauna, water quality and environmental flows. The report summarises the issues related to each topic which are considered relevant to the aims stated above. Additional research or investigations were not undertaken in this component of the project.

## 1.2 The Lake Connewarre Complex

The Lake Connewarre Complex consists broadly of Lake Connewarre, Reedy Lake, and Hospital and Salt swamps as well as associated sections of the lower Barwon River. In turn the Lake Connewarre Complex forms part of the Port Phillip Bay (Western Shoreline) and Bellarine Peninsula Ramsar Site. Lake Connewarre is a large tide-affected shallow lake system on the Barwon River between Geelong and Barwon Heads on the Victorian coast, west of Port Phillip Heads.

The lake forms a large part of the Barwon estuary, a permanently open estuary extending for 19 km (Mondon et al. 2003) from the river mouth at Barwon Heads. It holds about 42% of water in the estuary complex and the average depth was estimated in 1988 to be less than 50 cm (Sherwood et al. 1988).

Prior to European settlement salt water penetrated upstream to above Geelong. In 1840 and 1898 the upper and lower breakwaters were built to limit the upstream intrusion of salt water (Rosengren 1973). The river mouth is 24.5 km below the upper breakwater, and the entire estuary exhibits widely fluctuating salinity levels during the year. In drought conditions Lake Connewarre has been shown to be hypersaline over several months, but after heavy rains river discharge flushes the estuary with fresh water. These conditions impose a challenging physiological environment on the fauna and flora of the estuary and suggest that a persistent biota has evolved to be highly adapted to the variability of the system.

The Barwon River catchment covers 8,590 km$^2$ and contains some of the most intensively farmed land in Victoria. Additional potential impacts are from increased sediment load, water quality decline, pest plant and animal invasion and associated pressures on ecological systems. Industrial activity and residential developments contribute to the land use issues in the catchment.

This literature review is part of a larger investigation aimed at describing the existing biological, geomorphological and hydrological characteristics of the Lake Connewarre Complex, to better understand the diverse issues which may affect the complex and to determine whether and what interventions may be required.

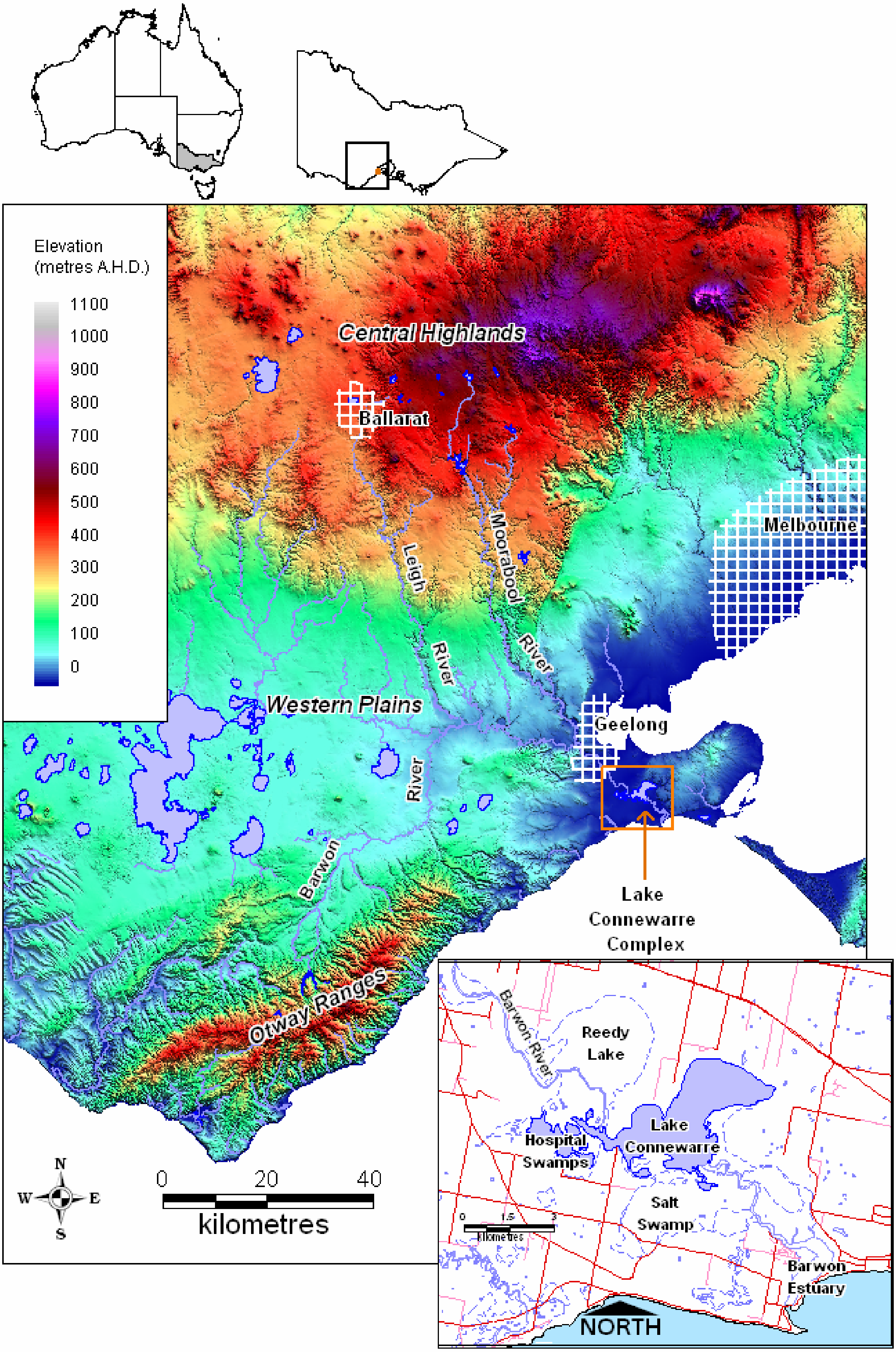


*Figure 1-1. Location of the Lake Connewarre Complex.*

## 2 A history of environmental change

This section sets the historical context for the evaluation of scientific data relating to the Lake Connewarre Complex. It provides a summary of literature concerning change in the land use immediate to the lakes and change in the river systems that contribute to the estuary. Particular attention is given to factors which may explain the sediment accretion observed within the timeframe of European settlement.

There has been no one historical study which examines environmental change in Lake Connewarre. Rather, a number of social histories at local and regional scales have been consulted to determine processes which may have impacted on the lake. Owing to the paucity of secondary published material an attempt to survey the range of primary sources was made. This section is a compilation of varied material which gives a tentative outline only of the lake's recent history. The potential value of particular primary sources is identified but not fully integrated into the reviews which follow this introduction. Time constraints prevented consulting Wathawurrung people, local family histories, the records of local interest groups and particular individuals with a long association with the lakes.

A review of Lake Connewarre's history extends our understanding of the estuary complex as a cultural landscape with natural values which are being actively promoted in its contemporary identity as a Ramsar site. It is a much changed place with a history of ”sludge” deposition, grazing, irrigation, pleasure boating, game shooting, industry outfall, water regulation, earthworks and past conservation actions not recognised as such now. An appreciation of the Lake Connewarre Complex's past values gives a context to what is understood as those 'natural' assets which underlie environmental research and reserve management.

Six periods which demarcate significant environmental change are characterised for the lake. In locating relevant material, the period between 1840 and 1980 has been the main focus. The pre-1840 period of Aboriginal land management overlaps with scientific studies referred to in other sections, especially those which review the geological and geomorphological history of the lake complex. For the post-1980 period the lake's recent history is relatively accessible and, more generally, there is greater knowledge of wider catchment and streamflow changes that have impacted on Lake Connewarre since the 1950s.

*Period 1.* 6,000 B.P. Aboriginal land management.

*Period 2.* 1840 – mid-1850s. Early pastoral - upper breakwater.

*Period 3.* Mid-1850s – 1890. Agricultural subdivision, gold mining waste begins, extensive riverfront industries, two major flood events, dredging, commercial shooting of wildfowl.

*Period 4.* 1890 – 1950. Agricultural decline, tourism, Harbour Trust management (lower breakwater), gold mining waste ends, Geelong sewerage schemes, river 'improvement' works.

*Period 5.* 1950 – 1980. Growth of Geelong and Bellarine Peninsula, SRWSC lower breakwater works, early conservation management, cement quarry discharge, erosion of lower Barwon, recreational lobby, high rainfall of early 1950s.

*Period 6.* 1980 – present. Ramsar wetland listing, Parks Victoria management, Hospital Swamp project, cessation of grazing and irrigation licences, estuarine studies, residential pressure.

## *2.1* Period 1. 6000 B.P. - Aboriginal land management

Occupation and management of Lake Connewarre by the Wathawurrung people is intimately tied to fluctuating sea levels and estuarine formations. This is well illustrated in Gill and Lane's appraisal (1985) of Coulson's 1930's findings concerning an oyster midden at Point Campbell. A single culture and stable population cannot be assumed for the period of Aboriginal land management. Scientific studies and accounts from the first years of contact with European settlers suggest that recent occupation was sustained by light harvesting of the lakes' natural resources and mosaic burning of the surrounding country.

The number of Wathawurrung occupying the estuary country declined rapidly from the late 1830s. In December 1840 one of the district's first pastoralists, Anne Drysdale, records a party of about 60 Wathawurrung camped in mia-mias near Boronggoop, along the River Barwon just west of Reedy Lake (SLV, Ms 9249, Drysdale Diary). By 1841 she observed only small groups very much in transit. In the country around her homestation, Drysdale described how a scattering of clumped trees punctuated the open grassland — young wattle, she oak and gum would form from "a burning of a large fallen tree, the ashes have the property of bringing up a clump of wattle or gums". Apart from descriptions of grassy open country close to her station there was just one reference to the tea-tree scrub in the direction of the lakes (Reedy). This 'scrub' was large enough for her friends to become lost in for several hours.

With Aboriginal management of the estuary country ceasing abruptly and with a short transition to a more intensive land management from the mid-1850s, the opportunities for a transitional landscape to develop must have been minimal. It may, however, have been different for those seasonally dry parts of the lake less attractive to the pastoralists and later agricultural landholders. If mosaic burning extended to those parts of the lake/swamp that were seasonally inundated, then perhaps an altered fire pattern did effect considerable vegetation change on marginally wet lands.

## *2.2* Period 2. 1840 – mid-1850s. Early pastoral - upper breakwater

Pastoral land use dominated the immediate lake environs from the 1840s through to the mid-1850s, and persisted for a longer period on the plains west of Geelong and along the Moorabool River. Spreadborough and Anderson's (1983) map illustrates pastoral home stations (Drysdale, Fenwick, Tait) surrounding Lake Connewarre (Figure 2-1).

These pastoral runs supported sheep grazing which extended out from home stations and outstations. At the end of 1841 Drysdale held approximately two thousand sheep divided into three flocks. One was based at Leep Leep, an outstation at Reedy Lake. Stock grazing was essentially a free range operation with minimal if any tree clearance involved. Small cultivation paddocks were sited near the home station. By the spring of 1841 Drysdale had organised the first ploughing of marshland near the river for potatoes, transplanted bush plants to her garden and constructed a sheepwash in the river (SLV, Ms 9249, Drysdale Diary). Details of stock numbers could be obtained for the estates bordering Lake Connewarre by consulting Commissioner of Crown Land Returns and Pastoral Run files.

There is no detailed vegetation record for this period but subdivision surveys reveal the tree species around the lakes, with some indicating vegetation density. As particular trees were used as survey markers for quite small subdivisions it would be possible to build a picture related to a landscape element such as elevation or soil type if the relationship was unknown. For particular sites adjoining the lake there is a representation of how vegetation of land and water merged.

Smythe's 1841 survey (PROV, Historic Plan Series, Moolap, Sydney M16) is of land north-west of Reedy Lake (Lagoon) along the river and up to Geelong's former town boundary. He listed gum, oak, honeysuckle, and wattle. An 1852 plan (PROV, Historic Plan Series, Moolap, Featr 442) extends Smythe's subdivision east across to Fenwick's and south to the lake boundary. Oaks and large gums were noted north of Reedy Lake, with oaks, gum and honeysuckle listed for north of Lake Connewarre. Box, blackwood and black wattle also appear as survey markers.

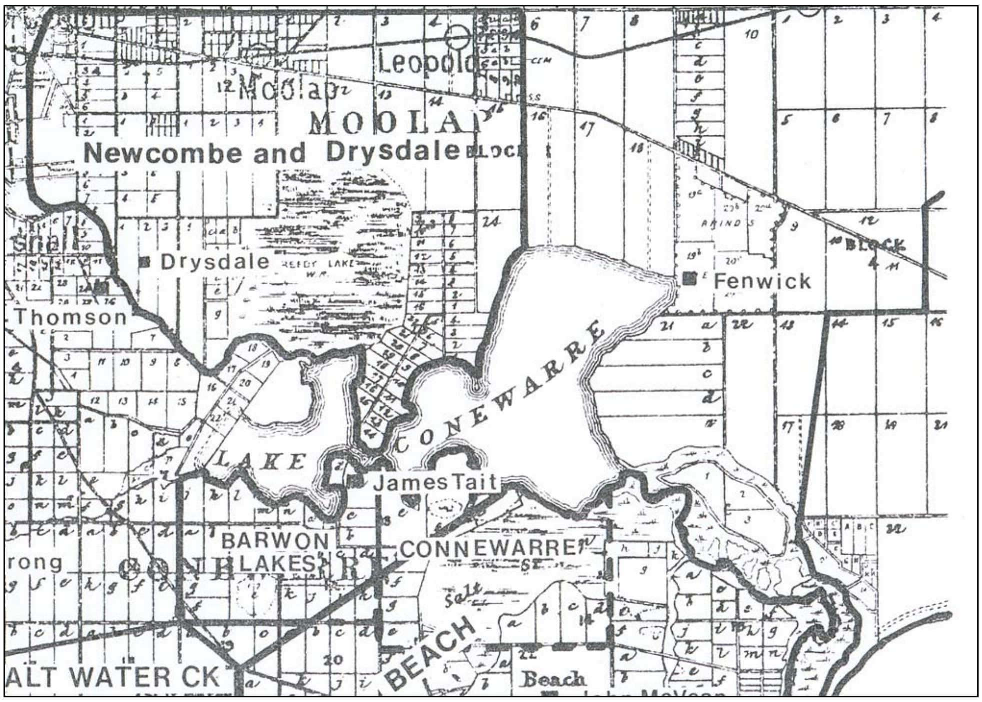


*Figure 2-1. Pastoral home stations (Drysdale, Fenwick, Tait) surrounding Lake Connewarre.*

*(Source: Spreadborough and Anderson 1983)*

Two 1855 maps (PROV, Historic Plan Series Sale 263, Byerley; Sale 269, Fynmore) of subdivisions near Tait and Fenwick give more detail. Immediately south of the lake (P. Conneware, Section 7, 13) was noted as “well grassed” and moderately to thickly timbered with sheoak and gum. Samphire and polygonum were on the lake margin (VPRS 44, Unit 8, item 272), samphire scrub was distinguished from samphire and, in the preparatory tracing, Bald Hill was noted as subject to inundation. Of the Connewarre blocks for sale Surveyor Skene (1855) observed that those fronting to the ”scrub” bordering Lake Connewarre were generally good agricultural land. Other blocks were ”considerably encumbered by stumps of she-oak which have been used for firewood – the gum trees still remain.“

Immediately north-east of the lake (P. Moolap, 19 and 20) gum, sheoak and wattle bordered the lake’s apron of grass flats and marshland was covered with ”coarse grass, flooded in winter”. An island of sheoak above the level of the marsh was noted. In the survey notes (PROV, VPRS 44, Unit 8, 1855) the Connewarre parish blocks were considered to be of greater value because of the ‘picturesque’ lake frontage.

An 1859 licence application for Pacey’s Island revealed the width of the channel to be planked for access was about 30 yards; that in heavy floods the island was almost submerged; that two small ”woods” of about one acre each grew at both ends of the island with the remaining area being of similar marsh vegetation to Lake Connewarre (PROV, VPRS 6605, Unit 25). From the first years of the twentieth century there is a considerable record for this island concerning the construction of levee banks and its land sale value, including Department of Agriculture analyses (PROV, VPRS 11559, Unit 343, ‘General’ Parts 1, 2, 3). Potentially it comprises an interesting record of change since early years of European land use.

A breakwater was constructed in late 1840 to ensure a fresh supply of water from the Barwon River for Geelong. It was mainly during summer that Ann Drysdale had to carry water from above the breakwater: “since the 25th of June [1842] the river has been fresh.” During the 1840s Geelong used the Barwon for its water supply. By mid-1850s this was not considered an option for water quality reasons, with an 1856 Board of Water Commissioners report making particular mention of contamination from floodwaters in the Leigh (Brownhill, 1955; Edmonds 2005). This report probably relates, in part, to the 1852 flood which in terms of water level was considered the most severe until the 1880 flood (Geelong Advertiser, see next section for more detail).

J. H. Taylor's 1855 Barwon River Survey (PROV, VPRS 44, Unit 470) followed this major flood event which delivered the first mining sludge to the region. His task was to assess the need for and impact of a breakwater near the estuary. Taylor advised against such a structure mainly for reasons of finance and engineering practicality. This report includes observations of the river and lake before the full impact of sluicing at Ballarat and ten to fifteen years after Geelong's breakwater. The following is a summary only:

> River upstream of breakwater and below Moorabool confluence: used four readings to determine quantity of water discharged during floodwaters of 1852: 31,710 cubic feet per second [897,926 $m^3 s^{-1}$]; water quality = fresh
>
> River from breakwater to entrance of lakes: average depth = 15 feet [4.6 m]; direction of stream = northern side of the river; water quality variable, during wet season, fresh, but other times quite salty; his observations taken April 1855, when salty [this is corroborated by the Drysdale diary]
>
> The lakes: depth of water varies from 3 inches [8 cm] to 8 feet [2.4 m]; bed principally composed of soft black mud with portions of gravel and sand; much of the lake covered with floating muck[?]; bed of lake covered mainly with sea weed and sea grass
>
> Lakes to Barwon Heads: depth of water varies from 6 to 9 feet [1.8–2.7 m] in the channel which is very winding and narrow; islands covered in samphire and polygonum scrub, soft black mud
>
> South side of the river: large marsh, trap [basalt] formation, to the east is limestone formation; soil sandy and in parts very stony; estimates most would be flooded; samphire and polygonum scrubs on the black mud impregnated with salt, marshes covered with tussock grass upon stiff clay soil
>
> North of the river: land nearly all purchased, light sandy soil, elevated
>
> Calculated that a breakwater at the heads would flood an area of 13 to 14 sq miles [34–36 $km^2$] with a depth between 3 inches [8 cm] and 4 feet [1.2 m] of which about 6 sq miles [16 $km^2$] of swamps and marshes would become "unwholesome" with fresh water; mud and alluvial matter brought down by river would be trapped, lake bed would rise and mud flats form.

Following the construction of Stony Creek and Korweinguboora reservoirs (early 1870s and 1911) water was pumped from the Barwon at Geelong in times of acute need only (1898, 1927).

The following reference may give more detail concerning the state of the rivers in this period: 'Final Report from the Select Committee upon the Supply of Water to Geelong' with the proceedings of the committee, minutes of evidence and appendices, 1858.

## *2.3* Period 3. Mid-1850s – 1890. Agricultural subdivision; gold mining waste begins; extensive riverfront industries; two major flood events; dredging; commercial shooting of wild fowl.

### *2.3.1 Agricultural subdivision*

The period of pastoral land use ended because the Bellarine Peninsula became part of an administrative unit known as the Settled District, aimed at dismantling squatter land occupation and encouraging land sales and subdivision in and around Melbourne and Geelong. This was not the case for much of the wider catchment area which, despite Land Acts of the 1860s, largely retained pastoral boundaries. During the 1870s and 1880s areas of the Otway forest were opened for selection. Assisted migration during the late 1840s and the gold rushes from the early 1850s swelled Geelong's population threefold by 1854. There was a new market of buyers for land apart from the land speculators (squatters and Geelong businessman) who had dominated prior land sales in the Parish of Moolap (Wynd 1988). Particularly small allotments (17 to 38 acres [6.9 to

15.4 ha]) were on the headland between Reedy Lake and Lake Connewarre, north of Campbell's Point.

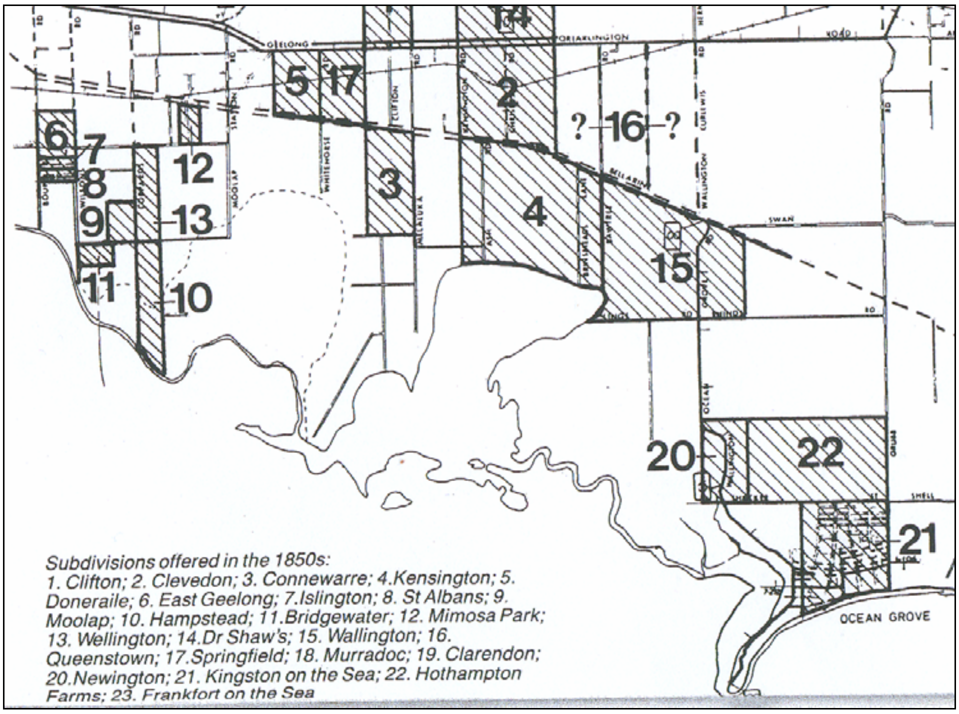


*Figure 2-2. Subdivisions offered in the 1850s.*

*(source: Wynd 1988)*

Details of some subdivisions are: Connewarre (3), 360 acres [146 ha] (23 to 40 acre [9.3 – 16.2 ha] lots); Kensington (Leopold) (4), 300 acres [121 ha] (14 to 40 acre [5.7 – 16.2 ha] lots) with a part re-sold as Kensington Park (6 acre [2.4 ha] villa lots fronting Lake Connewarre); St. Albans (8) became a township, 80 lots; Hampstead (10) was part of Drysdale's Boronggoop run; Wallington (15) was Fenwick's run (noted for freshwater springs, abundant timber and grand scenery of Lake Connewarre). Not all these subdivisions were taken up by agriculturalists as some were retained by investors for resale. In 1856 there were 125 occupants of purchased land in Moolap Parish (Wynd, 1988). This population growth could be tracked with census figures, but the trend was for gradual conversion to agricultural land use from the fifties. Wheat was the most important crop of the Bellarine Peninsula at this time, supported by mills at Drysdale and Portarlington.

As the new allotments were small and not always well watered, farmers were pressured to have unsold lands available as commonage, including Moolap Swamp, otherwise known as Reedy Lake, or Moolap Common, or part of the Connewarre Farmers Common. In the summer of 1866 farmers petitioned against this area being reclaimed under 'swamps and morasses' legislation by two applicants wanting to purchase 1900 acres [769 ha] (PROV, VPRS 242, Unit 27). It was considered the only "permanent supply of fresh water for cattle and domestic purposes" and in summer was the only part of the common where cattle could get feed. It was explained that many of the petitioners had purchased land near the Connewarre Lakes because of this access. A letter of support from the managers of the swamp reiterated these reasons and also referred to its value as a 'sporting field' as it attracted the greatest proportion of wild ducks for Lake Connewarre. Grazing rights may have been reversed temporarily in the early 1880s when it became a water reserve, but by the time Geelong Harbour Trust became managers early next century grazing licences were inherited.

More land sales followed the 1869 Land Act. The interest was so great that a group of Moolap landholders petitioned to protect the foreshore of Lake Connewarre from selection. By the early 1870s much of the land around Leopold was cropped with seaweed manure and shell being applied as fertiliser and conditioner. Individual landholders harvested shell and lime but it was also a commercial activity under seasonal licence on the commons associated with the lake (PROV, VPRS 242, Unit 498). Deposits one to two feet thick were dredged from specific licence sites (of petitioners in 1901, five wanted permanent sites of 20 acres [8 ha]). The summer casting season was one to two months for the Moolap Common and three months for the Connewarre Farmers and Big Marsh Common.

The production of onions and hay surpassed wheat by the 1870s (details could be sourced from the Agricultural Statistics in the parliamentary record). There must have been significant tree clearance related to agricultural activity at this time, although the tanning industry gave value to wattles (the value fluctuated but was often considered competitive with grazing). Rabbits were first reported for Wallington in 1871, with pressure from local government to eradicate the pest beginning ten years later (Wynd 1988).

### 2.3.2 Gold industry waste begins

Gold mining is most identified with Ballarat between the 1850s and 1870s when alluvial yields dominated. In terms of waste material, though, it was the continuous quartz mining production, very much strengthened by mechanical power, which became an ongoing source of pollution for the Yarrowee River right up until World War 1 (Bate 1979). It may be possible to assess the sedimentary loads with some accuracy by reference to: the quarterly production statistics available from the Reports of Mining Surveyors and Registrars; evidence in the Sludge Abatement Board Reports; and rainfall/flood data. Waste was sluiced into channels whenever floods or stored water was available. For the Moorabool diggings (Dolly's Creek, Tea Tree, Morrisons) 'alluvial' activity peaked in 1861. The deep lead mines along the Moorabool at Morrisons and quartz reef mines west of Dolly's Creek were active from the 1880s until the early twentieth century (Lawrence 2000). Once again production statistics combined with the history of erosion works at Morrisons could assist in quantifying the deposits. For the entire 60- to 70-year period of mining waste deposition, the Yarrowee River (and not the Moorabool River) would have carried the greatest loads as it was a receptacle for more than the adjoining operations.

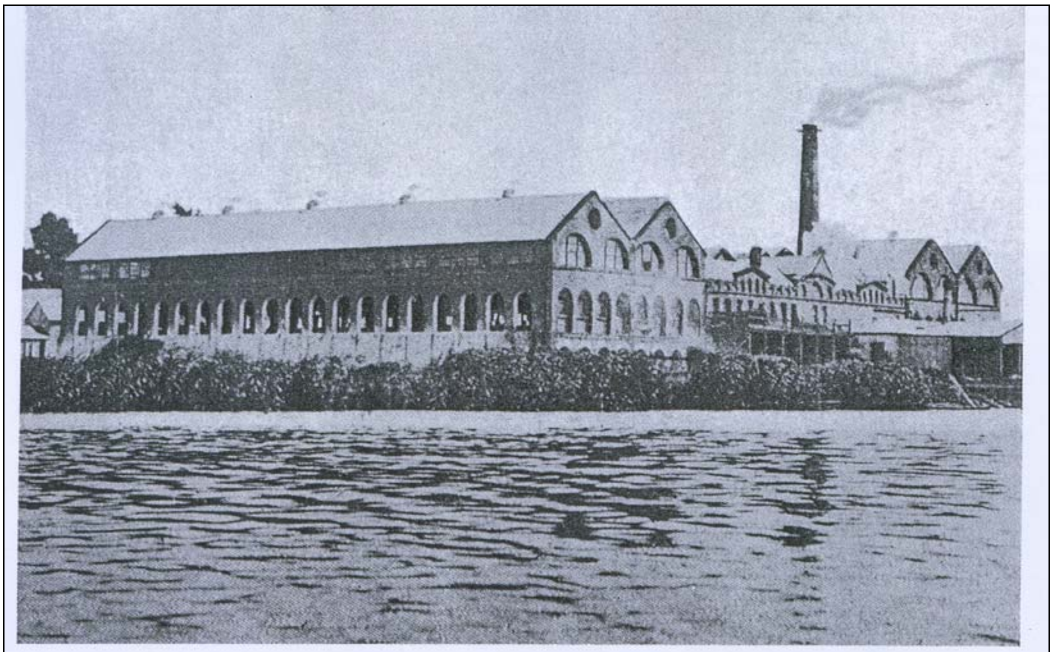
### 2.3.3 Riverside industries

Riverside industries both above and below the breakwater first appeared in the 1840s but were firmly established in the 1860s and 70s as local and regional markets expanded. These were highly polluting industries discharging directly into the Barwon. Below the breakwater at St Albans and what became Marshalltown (including Drysdale's former Boronggoop run) there were:

- Meatworks: boiling down works (e.g. tallow from 15000 surplus sheep per annum; earliest began at breakwater in 1844), Geelong Meat Preservation Company (subject to flooding… 'There were separate slaughter houses for sheep and cattle with sloping floors which eventually drained into the river'; became Wilson horse stud (1876) with a half mile frontage to the Barwon River. A race track built up by 3 to 4 feet [0.9 – 1.2 m] with tons of sea shell; St Albans Steam Bone Mill, beef salting factory.
- Tanneries: the largest (Brearley Bros) was on the south bank. At this one site (Figure 2-3) there were 140 tanpits and 40 limepits employing 100 men. A special after-hours school operated south of the breakwater to cater for the young men in riverside industries. Wattle bark from the Ocean Grove vicinity was highly valued. In a Soldier Settlement assessment for subdivision of Fenwick's home block (Rhinds, 1919) there remained a significant portion managed for wattle bark.
- Fellmongeries.
- Woolscouring.

Above the breakwater, there existed a glut of flour mills by end of the 1850s; woollen mills from 1865 (four of the largest were riverside); paper mills (first in 1854); a rope factory (1852); and cement works from 1889. [Information largely sourced from Brownhill (1955). More could be obtained by consulting local business registers and Geelong town plans].

In a report to the Commissioner of Fisheries (*Geelong Advertiser* 1875) it was stated that fishing had been almost abandoned in the Connewarre lakes, with low fish numbers attributed to the "pollution of water from the manafacturies along the Barwon, and the sludge from the diggings."



*The Australian Tannery, on the South bank of the Barwon river, a short distance from Marshalltown. In its heyday it was the largest and busiest of the tanneries. Brearley Brothers owned it. The industry encountered difficult times and faded out. Only the ruins now show where fine buildings and scores of tan pits used to be the centre of employment for many workers.*

*Figure 2-3. The Australian Tannery on the bank of the Barwon.*

*(source: Brownhill, 1955)*

*Figure 2-4. Tannery, fellmongery and O'Berne Wool Scourer, Breakwater.*

*(source: Fox, C. 1937; Picture Collection, LaTrobe Library)*

### 2.3.4 *Extreme flow events*

Major floods were recorded for 1870 and 1880, and were compared with the 1852 flood level (*Geelong Advertiser*). It should be noted that the construction of the lower breakwater postdated all three. Only the 1852 flood was the result of a sudden storm.

- The **September 1870** flood was in two stages: a minor one attributed to local stormwater after steady rain to be followed some 10 hours later by Ballarat water which saw the river rise 10 feet [3 m] above the 'ordinary level'. This was lower than the 17 feet [5.2 m] recorded for the 1852 flood, as measured by limbs fixed in riverside gums. There was some damage to riverside industry, including tanneries. The lower portion of Connewarre district was under water with significant crop damage.
- The **September 1880** flood was considered higher, by 6 to 10 feet [1.8 – 3 m], than the 1852 flood level. The bridges at Morrisons just held, but the Sharps Rd bridge at Meredith and two at Anakie were lost. Large timber was part of the flood debris. Extensive damage occurred to fellmongeries, tanneries, and woollen mills. Considerable wreckage from fellmongers was recovered at Point Campbell. Connewarre Boating Club lost its boathouse.

For comparisons with the 1952 flood, see Period 5 below.

### 2.3.5 *Dredging*

Calls to have the Geelong breakwater removed seem to stem from 1880 flood damage exacerbated by the railway embankment (*Geelong Advertiser*). A much criticised dredging operation for a new channel began in 1882 and continued for at least nine months. The dredging craft was considered totally inadequate for the task with only 600 by 22 yards [549 x 20 m] completed of the new channel, designed to be 3060 by 44 yards [2798 x 40 m]. A petition to parliament was organised in 1883 concerning:

- removal of the breakwater
- removing a sand bank at mouth of the Barwon River entering Reedy Lake
- cutting a channel through the sand bank at Howard's Point, Lake Connewarre
- cutting a canal through the sand bank at Barwon Heads near the entrance
- making the river navigable from Geelong to Barwon Heads for small vessels.

These measures were envisaged to encourage a plentiful supply of fish in the river and lake, to reclaim Reedy Lake and to develop fishing at the Heads. The extent of riverside industry raised the question of a navigable Barwon River, with the idea of pleasure steamers adding weight to the argument during the 1890s.

### 2.3.6 *Commercial shooting of wild fowl*

This was on a different scale from the activities of small landholders who supplemented their farm income with domestic quantities of wild fowl. Commercial shooting was challenged from at least 1871 with reports that 30 swivel guns were in operation on the lake with each party getting an average of 5000 ducks, presumably per season. Although there were calls for restraint, this practice was still being criticised on conservancy grounds in 1875.

## *2.4* Period 4. 1890 – 1950. Agricultural decline, tourism, Harbour Trust management (lower breakwater), gold mining waste ends, Geelong sewerage schemes, Barwon River 'improvement' works

### 2.4.1 *Agricultural decline*

Although onions became an important crop in the 1890s (eclipsing potatoes which peaked in the 1880s) this decade of rural depression marked an interruption to agricultural land use for the immediate environs of the lakes. Soldier settlement files give some sense of the decline of intensive land use for this area. Because there were few large landholdings on the peninsula there was little opportunity for subdivision, but the land assessments provide an interesting record for the early twentieth century. The file on Rhind's home block of 850 acres [344 ha], formerly Fenwick's pastoral run adjoining the north-east of the lake (Lot 19-20 Moolap parish) (PROV, VPRS 5714 Unit 1030), yields the following points of interest :

- an estimate of 15 acres [6 ha] liable to flooding by lake waters
- the location of permanent freshwater springs near the base of Fenwick Gully
- the high proportion of native grass (mainly kangaroo grass) to sown pasture (only 40 acres [16 ha] sown to rye)
- 180 acres [73 ha] timbered with gum, buloke and wattle
- bracken fern concentrated along creeks and gullies
- the location of ”onion land” (near lake margin), marl pits (dimensions given), and a wattle paddock (about 90 acres [36 ha])

Rhind held the farm for 25 years prior to sale (six lots of 120 to 180 acres [49 – 73 ha]), and although there had been limited cultivation of wheat, oats, barley, onions and other root crops, it was probably farmed less intensively than land with a longer history of subdivision. From the turn of the century agriculture temporarily gave way to grazing.

### *2.4.2 Tourism*

In this period Ocean Grove and Barwon Heads develop as seaside holiday towns, with boating and fishing on Lake Connewarre part of the tourist package. Wallington became an important link between Geelong and the coast offering visitors both visual and physical access to the lakes. An excellent representation of the lakes' new identity is H. Thacker's *Tourists' Guide to Geelong and the Southern Watering Places* (1892). Included is a description of a boating trip from Geelong to Barwon Heads by classics master J.L. Cuthbertson (a regular Saturday event with boys from Geelong Grammar from the late 1870s), who was to publish his verse in *Barwon Ballads* in 1893. These publications are in the romantic pastoral tradition but the lakes still emerge as being newly valued for picturesque, treed picnic spots and as a haven for boating tourists and recreational shooters. Although there is a consistent record of sailing on the lakes from the 1860s (Neale 1984), and no doubt family histories would reveal a geography of intimacy from this same period, it was from the 1890s that the inland waters registered on a broader cultural scale for European settlers. It is likely that the sudden growth of these seaside resorts so inclusive of Lake Connewarre as a scenic and sporting feature created some pressure for less exploitative pursuits.

A number of local histories (Edwards 1952, Loney & Holden 1972, Loney 1988, McKeown 1988) report the progress of these towns and include incidental items of potential interest. For example:

- Swimming baths were constructed on the south side of the river in 1895, but within a few years one could walk around the entire baths at low tide. The sand-filled structure was sold off in 1897.
- High tide (before 1890 but no date given) brought a whale and calf into Lake Connewarre. The calf died and the whale waited for several months before the next suitable tide.
- ‘Clematis’ camp was so called because of the abundance of the plant over the ti-tree.
- ‘Toorang’ (homestead near Point Campbell) was densely covered with golden wattle.
- A special type of sailing boat (flat-bottomed with a centreboard, unballasted) was used for Lake Connewarre.
- There was no difficulty in crossing the lake in early spring because of flood waters. The formation of sandbanks on river bends below the lakes could ground boats, but it was usually alright if they kept to the mid-stream.

- Freshwater for the Coffee Palace, a large guesthouse at Barwon Heads, was sourced from three wells.
- Boatmen congregated at Wallington to arrange daily excursion tours of the lakes.
- A 1920s experiment to dredge channel to create a navigable Barwon River (J. Loney, engineer; R. Holden, Geelong Harbour Trust) was abandoned as walls could not be maintained with the 'soft collapsible silt which forms the bed of the lakes', and there were 'problems at the mouth'.
- 700 acres of thatch grass was grown on Pacey's Island for the Geelong Salt works (managed by burning in later years).

Figures 2-5 to 2-8 are most likely from the 1920s, and represent the continuing identity of Lake Connewarre as a recreational space for local communities.

*Figure 2-5. Family group at 'Toorang', Lake Connewarre, 1920s.*

*Photograph courtesy of the Geelong Heritage Centre (1847/20)*

*Figure 2-6. Lake Connewarre scene, 1920s.*

*Photograph courtesy of the Geelong Heritage Centre (Photo 1847/23)*

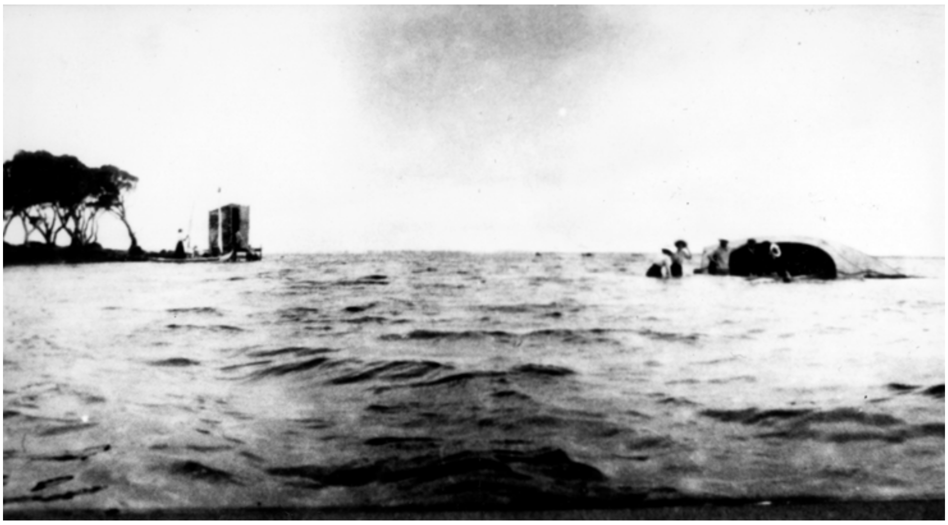


*Figure 2-7. Lake Connewarre scene, 1920s.*

*Photograph courtesy of the Geelong Heritage Centre (Photo 1847/22)*

*Figure 2-8. Duck shooting on Reedy Lake, 1920s: George Moore, Bill Dowsett and Bill Barker.*

*(Source: Mrs. T. McAllister, Newtown; Copied from "Balla-wein", Ian Wynd)*

### *2.4.3 Harbour Trust management*

From 1905-6 until the mid-1930s the Geelong Harbour Commissioners managed the Barwon River estuary and foreshore. Annual reports provide summary information on these 'Properties Controlled by the Commissioners' (including Reedy Lake, Connewarre Farmers' Common, Connewarre Lakes, Large Salt Swamp, Large Salt Lake, Murtnaghurk) but it is likely that more detailed engineer's and farm management reports could be sourced, especially in relation to dredging and levee bank construction. Enough is known to mark this period as the beginning of more deliberate water management for the lakes.

The new management supported the Commission's aim to generate income from productive land by converting Connewarre's common (c. 2000 acres [800 ha]) and the old racecourse reserve at Marshalltown into Sparrovale Farm, and by "reclaiming" Reedy Lake. These areas had been under grazing licences (usually administered by local government which deputised a party of local managers) during the pastoral and agricultural land use periods and became, controversially at the time, no longer ”common ground”. The lower breakwater was built in 1898, probably in response to the low rainfall period which prompted Geelong once again to draw supplies from the Barwon River. The Harbour Commissioners made use of the lower breakwater in the development of Sparrovale Farm. The following is an excerpt from the Commissioner’s annual report of 1907:

> *Reedy Lake contains an area of 1750 acres land and water, and during wet winters is subject to varying periods of almost total submergence, and it was felt by the Commissioners that this property, though subject to flooding, could be made vastly more valuable for summer feed by a definite control of the water at the right time, and satisfactory progress has been made in this direction. A good deal of the Lignum scrub, which besides occupying space gives cover to the rabbits, has also been rolled and burnt, and in the near future the Trust will obtain a much greater return therefrom.*

The trust retained occupancy but held an agreement with a cattle farmer from Skipton to graze the lake.

A 1906 survey report (PROV VPRS 5357/2365) of Lots 11 and 12 north of Reedy Lake/Swamp confirms this land use:

> *The Swamp was full at the time of survey (January 1906), and except in very prolonged dry weather, does not dry up. The water rushes and water lilies, which grow all over, afford great feed for stock, but drying up as the water disappears.*

Unlike Reedy Lake, Sparrovale was part of an endowment so that capital works were encouraged. Drainage was the main priority, with 722 acres [292 ha] drained by means of an open channel in the first year. Formerly the low-lying land was covered with two to three feet [60 – 90 cm] of water in winter with pools of water forming in summer after rain. Water grass and reeds gave way to “the luxuriant growth of strawberry clover round the margin….and is rapidly covering the whole area.” A rough subsurface profile is provided for the lower and higher parts of this land:

> *Lower ─ bed of shell a foot thick underlies the surface at about one foot; in the higher portions closer to the river bank the shell bed continues at the same level with a superimposed soil layer of five feet above the shell bed as a result of river deposition.*
>
> *Higher ─ First three inches clay, attributed to the large quantity of sludge diverted into the river; then “8 inches of good black soil, 8 inches of clay loam, one foot of shell, and finally clay.” Large excess of chlorine to a depth of five feet. Clay loam and sandy loam have not been deposited in the low-lying area.*

Details of subsurface drainage are also given.

> *1909: purchase of Lake View Farm to secure river frontage; about 340 acres cropped; heavy floods in August destroyed most and left pasture (dairy cows, pigs) with a heavy deposit of sludge; grading and draining continued over greater area; flood measures along river frontage.*

Clues to the commission’s management of Murtnaghurk Swamp, available from PROV 242/776, occur in the provision of licences for grazing, and summer shell and marl removal (for an adjoining asparagus farm).

### 2.4.4 Gold mining waste ends

Mining virtually ceased in Ballarat with World War 1, so that waste no longer entered the Yarrowee River in large quantity. In 1906 it was reported to the Board that “During the four years 1902 to 1905 inclusive the quantity of material crushed…within the catchment area of the Yarrowee was about 670,000 tons, a large part of which no doubt has gone into the Yarrowee.” Figures 2-9 to 2-11 show graphic images of battery sand near Shelford (from Report of Sludge Abatement Board, 1909, reproduced in Strom, 1954).

Figure 2-9. Sediment deposition in the Leigh River

*[A, B, C marked top left of image] A: Highest level of sand blown up by wind*
*B: Level of flats*
*C: Top of river bank*

*Yarrowee or Leigh River, about 1½ miles [2.4 km] above Golf Hill homestead, Shelford, 22/2/1910, showing siltation of hill lands by quartz mining operations at Ballarat (about 40 miles [64 km] upstream). The sand seen on the hill-sides has been blown there by winds from the adjacent flats and, at a height of 60 feet [18 m] above the river level, was 10 inches [25 cm] deep; the sand deposits on flats were 2 feet [60 cm] deep.*

Figure 2-10. Sediment deposition in the Leigh River.

*Golf Hill Estate, about 40 chains [800 m] upstream of the homestead; average depth of sand is 18 inches [46 cm] deposited within previous three years.*

*Figure 2-11. Sediment deposited along the Leigh River.*

*Golf Hill Estate, about 60 chains [1.2 km] above the homestead, showing bed, banks, and flats of Leigh River completely covered by battery sand to depth of two feet [60 cm], most of which lodged there in 1900.*

### *2.4.5 Geelong sewerage schemes*

A scheme to manage Geelong's domestic sewage was begun in 1911 and completed in 1916, but there was no provision for stormwater or industrial waste (Edmonds 2005). In 1905 Geelong's new Harbour Trust resisted pressure to remove obstructions from the river so that industries could transfer waste by boats. A particularly warm summer in 1920 triggered many complaints about the intolerable stench backing into Geelong. Once again criticism was voiced concerning the breakwater which held back sludge and stopped salt water flushes. This may explain the timing of the dredging experiment. A rudimentary system for industrial sewage was constructed in the early 1920s, and in 1930 the State Department of Health initiated a conference on the outfall which involved a detailed departmental assessment of the problem. Geelong's entire sewerage system was duplicated from the late 1960s.

### *2.4.6 Barwon River 'improvements'*

Barwon River 'improvements' through Geelong (straightening, reed cutting) begin in association with the State Rivers and Water Supply Commission (SRWSC). The Geelong Harbour Commissioners' 1927 report states:

> *Much remains to be done to exploit and improve the possibilities of the river and to make it what it is capable of being made, the best rowing course in the state and at the same time a source of enjoyment and recreation.*

River "improvements" continued in 1930 with weeds and sunken logs removed, banks levelled and grass seed sown. During the 1930s there was increasing publicity about the river as a neglected industrial backwater and successful moves to have Geelong's Waterworks and Sewerage Trust take over the management of the river through Geelong (Edmonds 2005). The initiative to have Reedy Lake proclaimed a Game Reserve seemed to stem from this Geelong base.

A summary list of river improvement works funded by SRWSC (up until 1954) for the wider catchment area is provided in the report of Strom & Forbes (1954). Activities included desnagging, removal of trees, bank protection, checking erosion, groynes, chutes, diversion and weed removal. In Strom & Forbes's assessment of siltation factors for the Barwon they alluded to landslips (both natural and land-use related) and to the scoured gullies in the country south of Winchelsea.

## *2.5* Period 5. 1950 – 1980. Growth of Geelong and Bellarine Peninsula, SRWSC lower breakwater works, early conservation management, cement quarry discharge, erosion of lower Barwon, recreational lobby, high rainfall early 1950s

### *2.5.1 Growth of Geelong and Bellarine Peninsula*

Post-war development of Geelong as an industrial centre involved the residential development of Geelong and the Bellarine Peninsula at a much greater pace than previously. In the 1920s the Ford motor vehicle manufacturing plant and fertiliser companies were established, and a resurgence of the woollen mills took place. Geelong's population doubled in the twenty years after the end of the war. Subdivisions reached a peak in the 1960s (72 in Whittington-St. Albans, 80 at Leopold, and 115 in the Ocean Grove area (Wynd 1988)). During the 1970s, while under the management of the Fisheries and Wildlife Division, land adjoining the reserve was purchased as a means of buffering residential pressure. Blocks with floodplain and wetland portions around Reedy Lake and Hospital Swamp were targeted. This boundary change continued into the 1980s. Details of these purchases and a 1973 report on subdivision are available from an archived Lands Department file (PROV, VPRS 11559/343). In 1974 a stormwater drain from Moolap Station Rd entered Reedy Lake, and was extended in 1977. There is also reference to a Commission of Public Health recommendation to discharge treated sewage from Leopold into Reedy Lake.

### *2.5.2 SRWSC lower breakwater management*

From 1935 most of Lake Connewarre moved from Geelong Harbour Trust management to become a Public Purposes reserve with the SRWSC assuming a greater role. The years of high rainfall in the early 1950s which prompted the Lake Corangamite Reclamation Project with its Woady Yaloak diversion in turn triggered works at the lake's lower breakwater. A series of temporary structures (fixed obstructions) in existence since 1898 were replaced with a SRWSC-designed and managed structure of 'floating gates' aimed at lowering the breakwater to cope with the extra volume of water envisaged with the Corangamite drainage scheme (Webster 1959).

With dry years in 1960-61 and in particular the drought of 1967, the impact of the new breakwater on Reedy Lake highlighted competing interests. SRWSC represented the irrigators needing water (for crops, mainly lucerne) and summer grazing (dairy) from Reedy Lake while the Fisheries and Game Division, and the local Association of Field and Game represented the duck shooters and more general conservation interests. In 1960, the Association of Field and Game presented a petition regarding the level of the lake with over 100 signatories. Before the breakwater was lowered, Reedy Lake was a foot [30 cm] lower than the river making river inflow easy, but the new structure held the river one foot lower than the lake. Over the next decade a number of solutions were found to raise the breakwater in summer and regulate flows. Some of these changes involved alterations or additions to the breakwater structure, including a flap-gate to prevent water outflow and a series of channelling works at Reedy Lake (SRWSC was reluctant to resource manual operation of the new structure). Field and Game lobbied with considerable success for water to remain in Reedy Lake over summer and to cover a minimum of two-thirds of its area. There was considerable sabotage, especially in 1967 when the lake was dry, by local farmers to adjust water levels to suit both grazing and irrigation requirements, and repeated cases of illegal diversions with at least one successful conviction (PROV VPRS 6008, Unit 800). Permits for water diversion increased in the 1970s for potato growers on the eastern side of Reedy Lake, where potatoes were cropped on land used previously only for grazing. The details of breakwater management are in files now archived (multiple in PROV, VPRS 11559, Unit 343; some were photocopied for this project including a 1960 SRWSC plan of the first proposed channel for Reedy Lake along with survey information and river levels).

### *2.5.3 Conservation management*

In 1961 Lake Connewarre came under review from the Wildlife Reserves Investigation Committee which recommended the area as one of the new State Wildlife Reserves (Geelong DSE Rs 12158;

PROV VPRS12011, Unit 172). The rationale for the lake's new wildlife status emerged from the belief that numbers of waterbirds had been in decline over the previous fifty years, and that the lowering of the river level with the management of the lower breakwater had adversely affected Reedy Lake. The new game reserve would 'rehabilitate particular swamps which have become uniform and of poor quality habitat during settlement', connect with other reserves to facilitate the east-west flight of birds across southern Victoria, and 'make greater public use of what is now mainly wasteland'.

Specific projects were optioned for different parts of the estuary complex. For Reedy Lake the need to control the river level so that it was "adequate" for wildlife and farming was demonstrated by the summer of 1961 which saw a low lake level but "river water flowing out to sea". It was hoped that the reserve would become more attractive to bird-watchers, shooters, and naturalists, and that fishing, canoeing and boating would be encouraged where there was no interference with reserve management. A Fisheries and Wildlife officer provided some interesting notes on the proposed reserve and some drawings of works planned for Reedy Lake, Hospital Swamp and Salt Swamp. These show islands formed from excavations, reed cover, tree planting plans etc. Waterholes in Salt Swamp were deepened and enlarged when dry to encourage water retention (1963, 11559/344). For Hospital Swamp it was noted with interest that parts were fresh water. There are details of banks constructed at the outlet of Reedy Lake in 1967, of a rubbish dump buried and weed management.

Management by the Division of Fisheries and Wildlife offered the lakes considerable protection during a development period when the conservation of wetlands was emerging as a new environmental value. For example there were moves to:

- Sluice and dredge for iron oxides (lease application, 1961).
- Dredge and remove sand for use by Alcoa at Point Henry (1962). Alcoa's (Saltpan Reclamation Co) application was for the Barwon River (upper breakwater to the heads) and for the Moorabool River. It is not clear whether permission for dredging in some areas was given.
- Build a breakwater in the lower Barwon near Sheepwash (1968, instigated by Leopold Progress Association and developed considerable momentum).
- Accommodate an army rifle range north of Reedy Lake (c. 1965).
- Build a marina with private moorings and housing at Pacey's Island (1973).
- Site local government (Geelong and South Bellarine) refuse dumps adjoining the reserve.
- Construct a channel from Corio Bay (1974).
- Increase discharge of saline groundwater from Australian Portland Cement works (1974). The Environment Protection Agency requested an environmental impact statement (EIS): "Flow Rates and Chloride Levels of the Barwon and Moorabool Rivers" and an associated report, "Chloride levels of Reedy Lake 1970-3". The cement quarry had a thirty year history of discharging groundwater into the Moorabool River with salinities monitored in-house. It was an application to discharge the larger amounts of groundwater due to an expansion of the quarry which triggered the EIS.

Not all requests were denied. An archery club from Kew was successful in harvesting reeds (*Typha*) from Reedy Lake for constructing archery targets (1975)!

The local members of the Field and Game Association instigated and implemented numerous works. Although this involvement was evident in the lake's earlier identity as a game reserve, the available record shows extraordinary commitment from the mid-1960s. For many years nest boxes were fixed on 11 foot [3.4 m] posts; trees were planted (the first record is of 600 trees on the western edge of the salt swamp, with species identified); and fences and signs were erected. They played a watchdog role and were tirelessly 'hands on'. There was one report (1969) of pesticides and weedicides contained in irrigation water (potatoes) draining into the lake (near Whitehorse Rd). Details of the Field and Game Association's involvement are available from the archived Crown

Lands files (11559/344; 343). Another support group was the Native Fauna Conservation Society. A 1968 map produced for one of their field days gives some vegetation and bird details. In contrast, the relationship between the reserve managers and the local landholders was predominantly one of conflict. A pre-occupation with fox numbers masked the locals' fear of land loss under compulsory acquisition.

Under Fisheries and Wildlife management the conservation agenda accommodated *stock grazing and irrigation licences*, and considerable lake bed works. In 1973 it was the Field and Game Association that questioned the grazing. This resulted in a summary report which revealed some ambiguity in the value of grazing. Six grazing licences were active for Lake Connewarre, the largest being for cattle on Reedy Lake (approx. 1700 acres [700 ha] designated). This particular licence (Hinchcliffe) was held for about twenty years. Because of the fluctuating water level the grazing pressure was very uneven, with most occurring from mid-November to April. To gain the benefit of what was an annual licence, the stocking was particularly heavy when the feed was available. At the time of this report Hinchcliffe grazed 289 cattle on the lake, and under another licence (Anderson) of just 23 acres [9 ha] there were 38 cattle and 100 lambs. Grazing pressure clearly impacted on the vegetation:

> *As the lake recedes grazing occurs mainly on spike rush, water couch and water tolerant species along the shallows, and pasture species on higher ground. In the autumn and dryer seasons as grazing becomes scarce, Lignum, cumbungi, round stemmed bulrush and phragmites are eaten as the water recedes further. This can be damaging.*
>
> *The only benefit derived from grazing is the reduction of plant material if it becomes over dense and restricts the use of areas by waterbirds. Grazing may then be beneficial from time to time with a specified number of animals.*

It was recommended that this licence be continued but with a reduced number of cattle. Details of other licences are available. Presumably these licences were cancelled as adjoining land was purchased and the conservation agenda strengthened. The current vegetation of Reedy Lake in particular needs to be assessed in the light of this history of moderately intensive grazing that has now ceased.

There were four annual permits to pump from Reedy Lake, two of which were active (details available). The permit, limited by availability only, for the largest area was Grinter's (16.5 ha). For more information on this period it may be possible to interview former reserve staff, in particular, Don White.

### 2.5.4 Erosion of the lower Barwon

Although the first power boat was reported in the Barwon River in 1908 it was from the mid-1960s that erosion, in particular of the south bank at Sheepwash, became an issue. Significant siltation had been observed as a result of speed boats and skiing. Pedestrian traffic along the banks was also causing observable damage. With the dry conditions of 1966-7 fisherfolk expressed concern for the sandbanking at the heads which created a narrow and shallow entry. Details of erosion works are in the archived Crown Lands files.

### 2.5.5 Recreational lobby

From the 1960s the Leopold Progress Association lobbied for greater recreational development of Lake Connewarre. Mollers Lane, Brinsmead Lane (where Leopold Sail and Boat Club formed in 1978) and later Ash Road frontage became a focus for beautification and development ideas. Frustration continued to be expressed about the number of roads which led "officially" but not "physically" to the lake, with pressure continuing into the 1980s when Bellarine Shire produced a well researched concept plan for improved access and foreshore development.

### *2.5.6 High rainfall early 1950s*

Strom & Forbes (1954) attempted a guarded comparison of floods in 1951 and 1952 with those of 1852 and 1880 (double the discharge of 1952), observing that, unlike the earlier major events, they resulted more from Otway than inland "weather". Strom & Forbes collected detailed discharge data (details photocopied) and relied on research by Culcheth (1882) and Kernot (1883). Strom & Forbes's assessment of the catchment also contains some comparative salinity readings for Victorian rivers which show the Barwon was surprisingly saline.

Construction of large capacity water supply reservoirs for the Barwon River (West Barwon, 1965) and Moorabool River (Lal Lal, 1972) was undertaken in this period.

## *2.6* Period 6. 1980 – present. Ramsar wetland listing, Parks Victoria management, Hospital Swamp project, cessation of grazing and irrigation licences, estuarine studies, residential pressure

The contemporary environmental condition of the Lake Connewarre Complex is described in the following sections of this report and a greater familiarity of material is assumed for this more recent history. Grazing and irrigation licences were terminated during this period and the complex was listed as a wetland of international importance under the Convention of Wetlands (Ramsar convention). It now forms a part of the Port Phillip Bay (Western Shoreline) and Bellarine Peninsula Ramsar site under the management of Parks Victoria. Although Parks Victoria files were not accessed for this historical analysis, those that were made available have been used as source material in the following sections of this report (refer to Sections 7 & 8 for more information).

One important development was the Hospital Swamp Project. In the early 1980s the Geelong members of the Victorian Field and Game Association "conceived, designed and constructed a scheme to divert excess water from the Barwon River to the Hospital Swamp." This is amply documented in a booklet printed in 1983 (copy available in archived file).

Urban expansion continued throughout this period and the increasing population has altered both the environmental and recreational uses of the Lake Connewarre Complex. Much of the history of these changes is covered in the other sections of this report. A more detailed analysis of the history of this period (in the context of the past 200 years) is challenging because the source materials are less accessable. While such an analysis may be a worthwhile research project in the future, it exceeds the budget limitations, timeline and scope of this review.

## *2.7* Summary and Issues

The Lake Connewarre Complex has undergone significant change within the historical timeframe because of altered land use in the immediate and wider catchment areas and, more directly, because of activities in the complex itself. This brief survey of selected primary records and existing historical material suggests that the extent of this change has not been fully assessed and has perhaps been undervalued in scientific studies. A tentative framework of six periods to demarcate environmental change is identified to encourage greater links with contemporary investigations into the Lake Connewarre Complex.

An appreciation of the Lake Connewarre Complex as a cultural landscape raises the following questions:

**1. Sedimentation**

- Has the proportion of local sediment (lake bed earthworks, irrigation, dredging, pollution, agriculture) relative to the Moorabool, Barwon and Leigh catchments been underestimated in the current understanding of sediment transfer and accretion?

- Has there been adequate appreciation of the extent of both mining and industrial sedimentary input into Lake Connewarre over a seventy year period (1850-1920), with perhaps the greatest loads transported in the late 19th century rather than the 1850-60s?

## 2. Flora

- Did the cessation of Aboriginal burning of the lake margin vegetation and the absence of a pastoral fire regime (or initial heavy stock grazing) produce significant vegetation change?
- Has the Lake Connewarre Complex vegetation been interpreted in the light of the extensive history of stock grazing?
- Can the analysis of historical material for particular sites (Fenwick Gully, Tait's, Pacey's Island) assist in vegetation studies?
- Is the chemistry of industrial as well as mining pollution required to understand lake ecology?

## 3. Hydrology

- Is there information about the prior regulation of lake water, especially in relation to Reedy Lake and Hospital Swamp, which needs to be incorporated in an analysis of hydrological systems?

## 4. Management

- Has the significance of Lake Connewarre as a place high in natural values for local and regional communities been adequately considered in its recent management? The question of access, in particular, has been controversial for the last thirty to forty years.
- Has the extraordinary contribution of groups such as the Field and Game Association and various conservation groups been fully acknowledged and has the potential of this positive energy been addressed in a management plan?
- Is there a new strategy to minimise harmful effects of further residential development on the natural values of Lake Connewarre? The old strategy was to purchase adjoining land as a buffer zone.

# 3 Geology

In describing the geology of the region, it is convenient to address the stratigraphy (the succession of rock units from oldest to youngest) and the structural geology (the modification of the stratigraphy by subsequent tectonic processes to produce features such as faults and folds). Because geology is an historical science, it is calibrated against the geological timescale (Table 3-1).

| Era | Period | Epoch | Numerical age of epoch (millions of years) |
|---|---|---|---|
| Cainozoic | Neogene | Holocene | 0-0.01 |
| | | Pleistocene | 0.01-2 |
| | | Pliocene | 2-5 |
| | | Miocene | 5-23 |
| | Palaeogene | Oligocene | 23-34 |
| | | Eocene | 34-56 |
| | | Palaeocene | 56-65 |
| Mesozoic | Cretaceous | Early Cretaceous | 100-146 |

*Table 3-1. The portion of the geological timescale pertinent to the Bellarine-Lake Connewarre Complex area. Epochs are subdivisions of periods which, in turn, are subdivisions of eras. Most are millions of years in duration. Numerical ages are rounded from Gradstein et al. (2004).*

## *3.1* Regional stratigraphy

### *3.1.1* *Otway Group*

The oldest rocks belong to the Otway Group, which also occurs abundantly in the Otway Ranges and the Barrabool Hills. The Otway Group is kilometres thick and consists of interlayered sandstone and mudstone. The sandstones are relatively poor in quartz but rich in feldspar and fragments of volcanic rocks. When fresh (unweathered), they are a dark grey-green colour due to the presence of chlorite. The sediments of the Otway Group were eroded largely from volcanic rocks and deposited in a system of rivers, lakes and floodplains while southern Australia still resided in the Antarctic circle. The system occupied the rift valley that opened as Australia began to separate from Antarctica in the Early Cretaceous.

### *3.1.2* *Eastern View Formation / Werribee Formation*

The Eastern View Formation and Werribee Formation do not outcrop on the surface, but are known from bore records to occur at depth under the Bellarine Peninsula (Holdgate & Gallagher 2003). They consist of non-marine conglomerate, sandstone, siltstone and claystone interbedded with brown coal seams. The formations underlie the Older Volcanics, and are assumed to be Late Palaeocene or Early Eocene in age.

### *3.1.3* *Older Volcanics*

At the surface, an unconformity, or angular discordance, separates the Otway Group from the overlying Older Volcanics. The Older Volcanics are basalts and fragmental rocks (pyroclastics) that were erupted across Victoria either in the Palaeogene or the Neogene. At Curlewis, where the volcanics are probably Eocene in age (Abele 1988), Coulson (1933b) described the basaltic neck of a volcano associated with a 100-metre thickness of pyroclastics.

### 3.1.4 Fyansford Formation

Calcareous clays, marls and impure limestones with abundant fossils belong to the Fyansford Formation. The Fyansford Formation crops out in a narrow band on the eastern shore of Lake Connewarre as well as around Geelong (Spencer-Jones 1970). The fossils provide excellent age control and show that the formation is Miocene.

### 3.1.5 Moorabool Viaduct Formation

The Moorabool Viaduct Formation is a thin (generally no more than a few metres thick) unit of sand and sandstone cemented with iron oxide (Spencer-Jones 1970) which is widespread both on the Bellarine Peninsula and generally in south-western Victoria. Fossil shellfish (bivalves) recovered from the shore of Lake Connewarre indicate both a marine environment and a Pliocene age for the unit (Coulson 1935, Abele 1988).

### 3.1.6 Newer Volcanics

Geologically recent volcanism in Victoria is represented by the Newer Volcanics. The Mt Duneed basalt flow, part of the Newer Volcanics, encroaches upon the Lake Connewarre Complex and is a critical component in the development of the complex. One lobe of the flow dammed the Barwon River at Tait's Point to form Reedy Lake and a second at Pelican Rocks marks the approximate downstream limit of Lake Connewarre (Coulson 1935, Cecil et al. 1988). A third lobe meets the coast at the mouth of the modern Barwon River and underlies The Bluff there.

### 3.1.7 Quaternary

The youngest geological units are sediments that have been deposited in the last two million years, including those of the Lake Connewarre Complex. Sedimentation continues in the wetland areas surrounding the Bellarine block. Deposits include sands, silts, clays and limestone. Limestone of the Bridgewater Formation was deposited as wind-blown lime sand to form coastal dunes before the last glaciation, and has since been cemented. Coastal barrier sands, beach ridges and lacustrine muds and sands partly surround the higher portion of the Bellarine Peninsula.

## 3.2 Structural geology

The major structural features of the Lake Corangamite Complex–Bellarine Peninsula are the elevated Bellarine block and the depressed Moolap block (Figure 3-1). Forces in the Earth's crust have raised the Bellarine block a minimum of some hundreds of metres, while the Moolap block, including the Lake Corangamite Complex, has subsided. The effect is that the Bellarine block is dominated by non-deposition and erosion whereas the Moolap block is a locus of sedimentation.

Uplift of the Bellarine block occurs along three structures, the Curlewis Monocline in the north, the Bellarine Fault in the east and an inferred fault in the west (Spencer-Jones 1963, Abele 1988).

- The sinuous Curlewis Monocline defines the shape of the coast of Corio Bay from Portarlington almost as far west as Leopold. A monocline generally passes down into a fault at some depth below the surface, but lacks the fracturing that characterises a fault. Rather, it is type of fold where a zone of steeply dipping rocks gives way laterally to near-flat-lying rocks.
- The Bellarine Fault is a south-westerly–trending structure that is parallel to and a little west of a line between Indented Head and Point Lonsdale. Downthrow is to the east.
- The inferred fault trends south-west from the coast, just east of Leopold. Downthrow is to the west. The fault follows the strip of land that separates Reedy Lake from Lake Connewarre to the Barwon River, where it dies out.

The disappearance of the inferred fault, together with the lack of a bounding fault to the south, suggests that the Bellarine block is tilted to the south, with the greatest uplift along the Curlewis Monocline. This has two consequences:

- The oldest rocks exposed on the Bellarine Peninsula, the Otway Group and the Older Volcanics, come to the surface along the Curlewis Monocline between Clifton Springs and Portarlington.
- Even though Lake Connewarre is east of the inferred fault, it is in an area of subsidence, that is, an area able to host wetlands and to accumulate sediment.

### *3.2.1 Neotectonics*

Earthquakes which have been recorded in the past century or more indicate that the faults are still active. A preliminary assessment of the seismic risk for the City of Greater Geelong (P.J. Yttrup & Associates 2000) indicated that at least eight faults in the area can be considered active. These include the inferred fault from Point Henry to Lake Connewarre (regarded as an east-dipping thrust fault). The Bellarine Fault has recorded earthquakes to Richter magnitude 3.5.

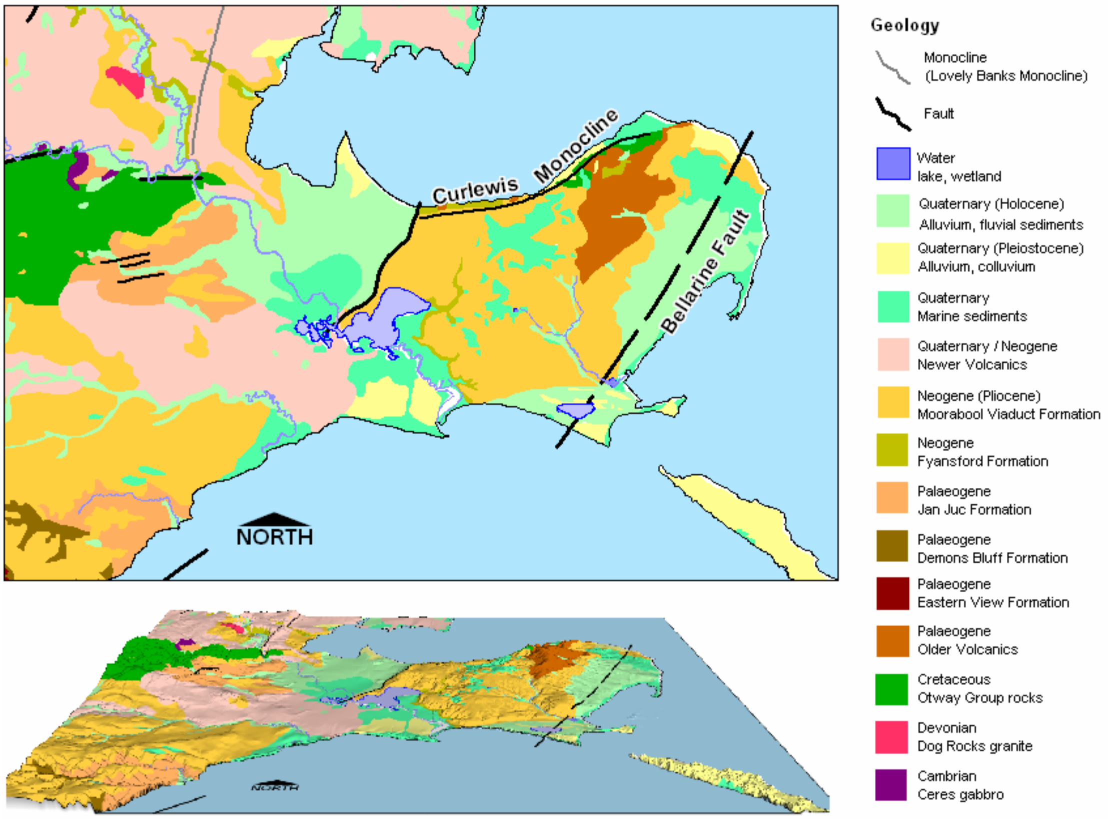


*Figure 3-1. Geology of the Bellarine Peninsula and environs.*

*Source: GeoScience Victoria, 2003*

## *3.3* Geological evolution of the Lake Connewarre Complex

Aspects of the geology of the Lake Connewarre Complex have been documented by a number of studies including: Daintree (1862a) who geologically mapped the region; Coulson (1933a,b, 1935) who investigated the lake sediments and interpreted its geological evolution; Spencer Jones (1963, 1970, 1973) who undertook regional mapping in the area; Ladd (1971) who geologically mapped the area; Rosengren (1973) who described the geological evolution of the lakes; Cecil et al. (1988) who undertook a detailed sedimentological study of the Lake Connewarre Complex; Bird (1964, 1993, 2000) who summarised the estuary evolution; Stokes (2002) who studied the sediment movement in the estuary; Muller (2003) who undertook a rockfall assessment at The Bluff at Barwon Heads; and Mockunas (2006) who investigated the hydrogeology of Reedy Lake.

A simplified geological map based on the paper by Rosengren (1973) and taken from Bird (1993) illustrates the main features of the site (Figure 3-2).

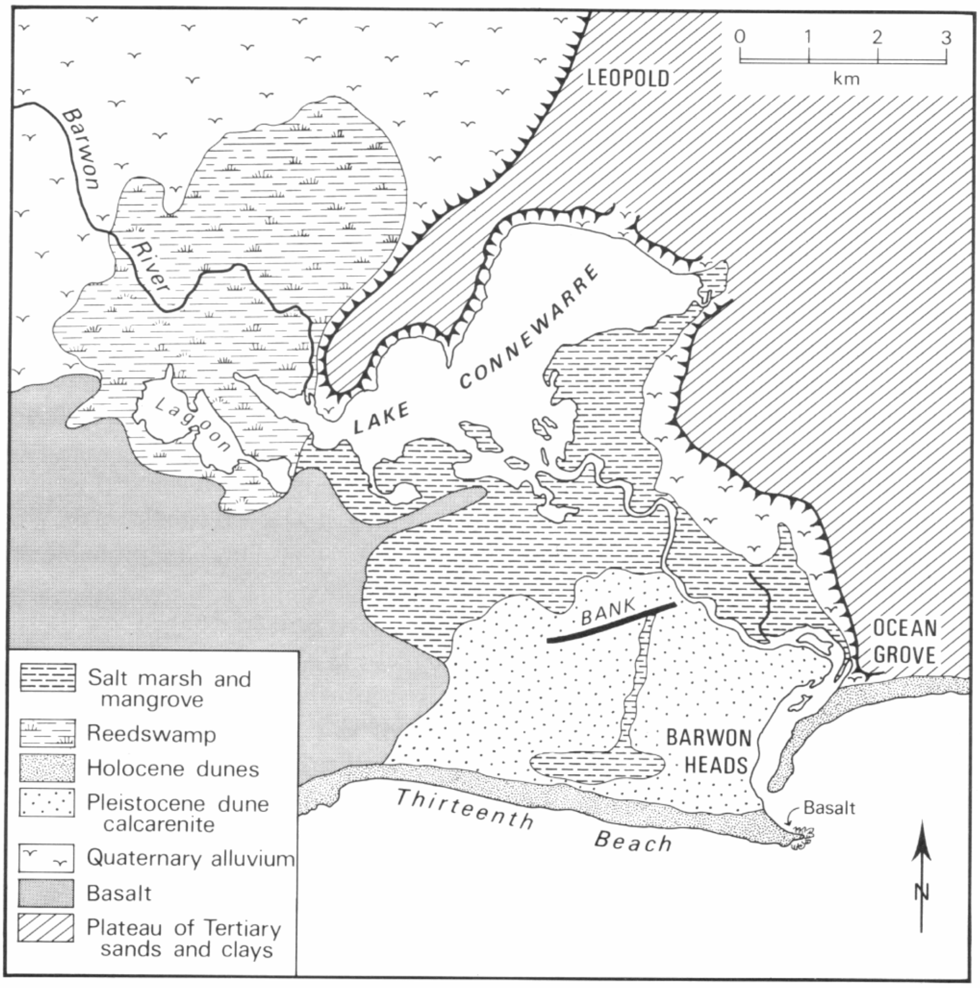


*Figure 3-2. Simplified geology of the Lake Connewarre Complex.*

*Source: Bird, 1993*

In summarising the literature cited above, the main events in the geological history of the site are as follows:

- The Gondwana break-up in the Late Jurassic to Early Cretaceous initiates the Otway Basin, which fills rapidly with sediments derived from the erosion of large volcanoes to the north or east. These sediments are compressed into the sedimentary rocks of the Otway Group which underlie the entire Bellarine Peninsula.

- Uplift across southern Victoria at the end of the Early Cretaceous restricts further deposition. Subsidence along the north-easterly–trending faults flanking the uplifted blocks forms the Torquay and Port Phillip Basins. The basins are separated by a submerged ridge along the axis of the Bellarine Peninsula.

- Numerous sea-level fluctuations during the Palaeogene and Neogene result in a variety of sediments being deposited in the basins, including alluvial, marginal-marine and shallow-marine. During this time, the Eastern View Formation/Werribee Formation, the Older Volcanics and the Fyansford Formation are deposited.

- An extensive marine transgression in the early Miocene inundates the Bellarine Peninsula, and the coastline migrates significantly to the north. Uplift of the Bellarine Block probably commenced in the late Miocene when the tectonic stress field for Victoria changed to its present state of strong E-W to SE-NW compression.

- As a result of the uplift, an embayment develops between Torquay and Ocean Grove that narrows to a wide channel towards Corio Bay. Inundated by a shallow sea, the floor of the embayment comprises the clays of the Miocene Fyansford Formation.

- The sea retreats in the late Pliocene leaving a series of east-west trending barriers or strandlines. The barriers are principally composed of dense shell beds and minor sand beds in the embayment. On the slopes of the Bellarine Block, the sands of the Moorabool Viaduct Formation are deposited by the retreating sea.

- Volcanic activity in the late Pliocene or early Pleistocene in the form of eruptions at Mount Duneed results in lava sheet flows and the deposition of basalt. As the lava flows eastwards towards the area now occupied by the Lake Connewarre Complex, it separates into three lobes. The drainage of the ancient Barwon River system is strongly disrupted by the volcanism, and the river is temporarily blocked above Lake Connewarre. Lagoonal environments develop behind the lava flows to form the precursors to Reedy Lake, Hospital Swamp, Lake Connewarre and Salt Swamp. The lakes are subsequently connected by their present channels when the river finally erodes through the basalt barriers.

- Sedimentation in the Quaternary is influenced by sea-level changes in response to glaciation. Approximately 125,000 years ago the sea levels were around 7.5 m higher than present, and the Bellarine block is believed to have been an island in a shallow sea. As the sea levels dropped in response to the following ice age, a barrier develops between the Bellarine Peninsula and Cape Shank. The remnants of this barrier now form the headland at the mouth of the Barwon River, known as The Bluff.

- Sea levels continue to recede, dropping to at least 150 metres below present levels by 20,000 years ago. During this time the climate was arid and cold, with evidence of frequent high wind events. The Lake Connewarre Complex was situated well inland, with the shoreline west and south of Tasmania. As the ice-age ends, sea levels rise at a rapid rate, averaging just over 1 m per century. By 6000 years ago the sea levels were approximately 2 m higher than present and have fallen to their present level since around 3000 years before present. In the past century the sea levels are believed to have risen slightly.

## *3.4* Summary and Issues

1. The Lake Connewarre Complex is a relatively recent feature of the Bellarine Peninsula, having been formed since the late Miocene and only developed into its current state during the Quaternary. The environment of the complex has undergone dramatic changes over the past 125,000 years, which suggests that the majority of the sediments and landforms are very recent.
2. The sea level fluctuations in the Lake Connewarre Complex during the Holocene have been dramatic. Further research into the depositional history and the fossil record preserved in the Lake Connewarre Complex may provide an analogue for understanding the effects of future climate change.

# 4 Geomorphology

The geomorphic units of Victoria are organised into hierarchical tiers. The Lake Connewarre Complex lies at the extreme eastern limit of the Victorian Western Plains, adjacent to a block of the Victorian Southern Uplands. These form two of six *geomorphic zones* in Victoria (Joyce et al. 2003, Robinson et al. 2003). The majority of the complex occurs on the sedimentary plains, along with the volcanic plains in the south-western sector and the dissected low hills of the Bellarine Peninsula in the north-east portion of the study area (Figure 4-1).

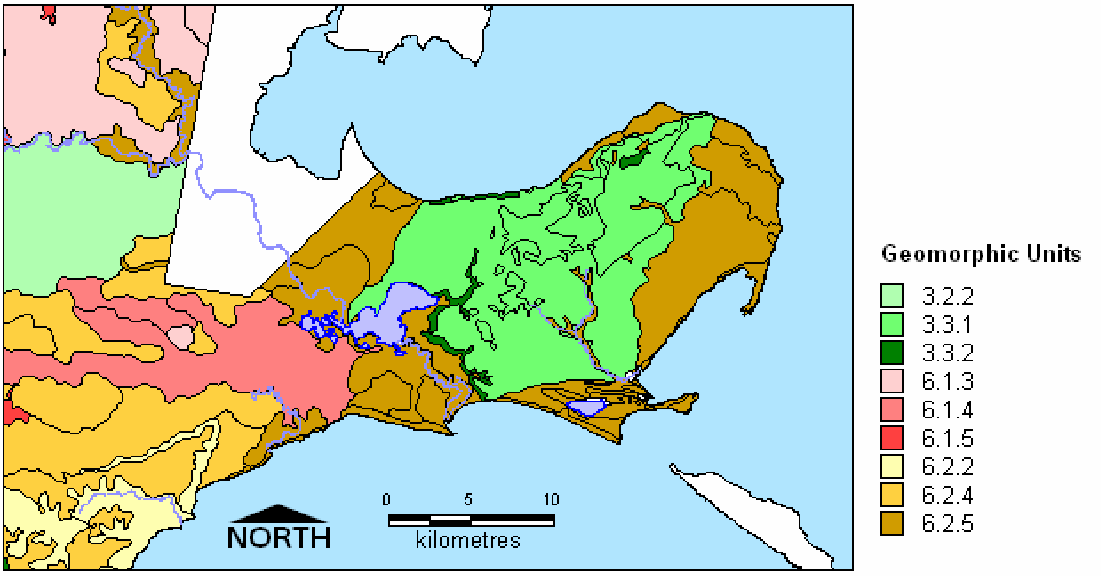


*Figure 4-1. Regional Geomorphic Units.*

*Source: Robinson et al. 2003*

| **Unit** | **Title / description** |
|---|---|
| **3** | **Victorian Southern Uplands** |
| ***3.2*** | ***Dissected Upland*** |
| 3.2.2 | Dissected ranges (e.g. Barrabool hills) |
| ***3.3*** | ***Dissected low hills*** |
| 3.3.1 | Plateau (Bellarine Peninsula) |
| 3.3.2 | Rolling hills (e.g. Barwon Downs) |
| **6** | **Victorian Western Plains** |
| ***6.1*** | ***Volcanic plains*** |
| 6.1.3 | Plains with poorly developed drainage (e.g. Wingeel) |
| 6.1.4 | Plains with well developed drainage (e.g. Cressy) |
| 6.1.5 | Lakes, swamps, lunettes (e.g. Lake Corangamite) |
| ***6.2*** | ***Sedimentary plains*** |
| 6.2.2 | Dissected plains (e.g. Heytesbury) |
| 6.2.4 | Plains and plains with low rises (e.g. Duck Hole Plain) |
| 6.2.5 | Alluvium, alluvial terraces, floodplains and coastal plains (e.g. Moolap Sunklands) |

*Table 4-1. Regional Geomorphic Units.*

*(The unit numbering relates to the three tiers currently employed).*

## 4.1 Site geomorphology

The Lake Connewarre Complex is part of the Moolap Lowland (Marsden 1988), a depression that abuts the Bellarine high to the east (Figure 4-2). The surface of the Moolap Lowland is approximately 7 m above sea level. The Lake Connewarre Complex is a system of alluvial, lacustrine and estuarine landforms within the sedimentary plain of the Moolap Lowland.

The Bellarine high, adjacent to the Moolap Lowland, is a topographic dome (Figure 4-2). It slopes gently toward the sea on its southern and eastern sides and toward the Lake Connewarre Complex on the west, though steepening considerably adjacent to the lake complex. On the north, the slope toward Corio Bay is relatively steep and reflects movement along the Curlewis Monocline. The maximum elevation on the Bellarine Peninsula is at Mount Bellarine which rises to 130 m.

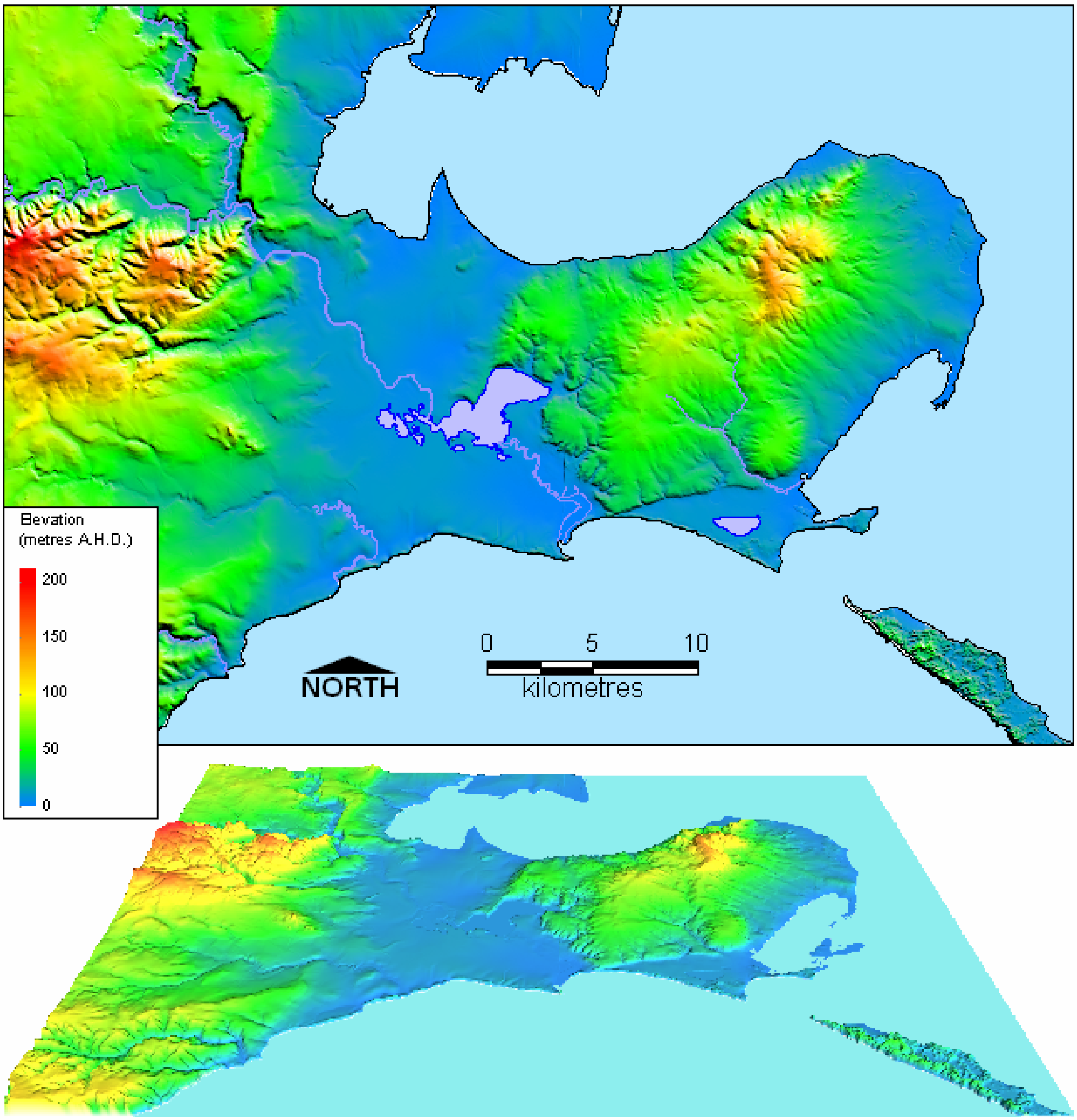


*Figure 4-2. Regional physiography of the Moolap Lowland, containing Lake Connewarre Complex, and Bellarine high.*

*Note: constructed from Corangamite GIS data sets (Dahlhaus 2002). Oblique view is vertically exaggerated 10 times, viewed looking due north, at an inclination of 35°.*

Landforms associated with the Lake Connewarre Complex are listed in Table 4-2.

| Environment | Landform |
|---|---|
| fluvial | channel |
| | levees |
| | floodplain |
| lacustrine | basin |
| | delta |
| | shore |
| estuarine | channels (1st, 2nd & 3rd order) |
| | marsh/swamp land |
| | flood-tidal delta |

*Table 4-2. Landforms of the Lake Connewarre Complex.*

*Sources: Cecil* et al. *(1988), Rosengren (1973), Stokes (2002).*

### *4.1.1 Soil-landform units*

Soil-landform units were mapped and described for the Corangamite Land Resource Assessment (Robinson et al. 2003). The soil-landform units relate to the third-tier geomorphic units and are described in terms of their soil profile, landform, climate, vegetation and land characteristics. The descriptions include photographs, 3-D block diagrams and topographic section profiles. Thirteen soil-landform units are described for the area of the Lake Connewarre Complex (Figure 4-3). Soils in unit 205 - *urban development* and unit 206 - *permanent water bodies*, were not mapped in detail.

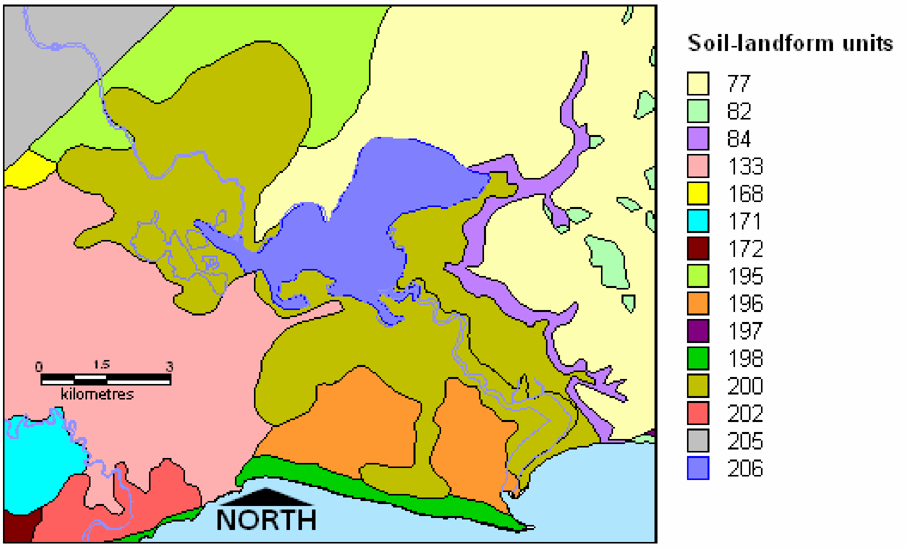


*Figure 4-3. The distribution of soil-landform units around the Lake Connewarre Complex.*

*Source: Robinson et al. 2003*

The soil-landform units are mapped at a scale of 1:100,000 and were derived from previous mapping and soil surveys conducted in the region. Over 165 detailed soil profiles were mapped for the Corangamite Land Resource Assessment project, including a few (perhaps a dozen) in the general area surrounding the Lake Connewarre.

Detailed descriptions of the individual soil-landform units are appended (Appendix A).

## 4.2 Geomorphic processes

Aspects of erosion and sedimentation within the Lake Connewarre Complex and the lower Barwon River are examined in Section 5, Sedimentation. The most apparent modification to the geomorphic processes is the bunding of Pacey Island in the lower Barwon, which has resulted in the destruction of some intertidal channels and alteration of the shape, length and position of others (Stokes 2002).

At a regional scale, each soil-landform unit shown in Figure 4-3 has been rated in terms of its susceptibility to soil degradation processes (Table 4-3). The ratings reflect the 'bare earth' susceptibility and have not been assessed in relation to current land-use practices.

| Soil-landform unit | Susceptibility to: | | | | | |
|---|---|---|---|---|---|---|
| | Sheet & rill erosion | Gully & tunnel erosion | Mass wasting | Wind erosion | Soil structure decline | Soil water-logging |
| 77 | 6 | 4 | 4 | 6 | 7 | 7 |
| 82 | 8 | 5 | 2 | 8 | 7 | 3 |
| 84 | 8 | 8 | 6 | 4 | 5 | 5 |
| 133 | 5 | 5 | 3 | 3 | 7 | 8 |
| 168 | 6 | 6 | 4 | 3 | 6 | 6 |
| 171 | 6 | 6 | 5 | 6 | 8 | 8 |
| 172 | 6 | 6 | 5 | 6 | 8 | 8 |
| 195 | 6 | 6 | 1 | 7 | 8 | 8 |
| 196 | 6 | 6 | 1 | 7 | 8 | 8 |
| 197 | 8 | 8 | 3 | 7 | 8 | 8 |
| 198 | 6 | 3 | 8 | 8 | 7 | 2 |
| 200 | 3 | 1 | 1 | 7 | 8 | 10 |
| 202 | 3 | 1 | 1 | 5 | 8 | 10 |
| 205 | Urban area – not rated | | | | | |
| 206 | Water bodies | | | | | |

*Table 4-3. Susceptibility of soil-landform units to soil degradation processes (1 = very low; 10 = very high).*

*Source: Robinson et al. 2003*

### 4.2.1 Erosion and landslides

A number of studies related to erosion and landslides in the region have been undertaken in recent years.

- Muller (2003) studied the rockfall hazard associated with The Bluff, a coastal headland at the mouth of the Barwon River at Barwon Heads. The study identified eight types of rockfall failure mechanisms and at least 63 larger rockfall events over the past 100 years. Periods of prolonged or intensive rainfall were identified as the major trigger (Muller et al. 2006).

- A comprehensive study of erosion and landslides within the boundaries of the City of Greater Geelong was undertaken by GHD (2004a). The study was aimed at providing advice to the municipality on the implementation of an Erosion Management Overlay in its municipal planning scheme. The project resulted in the establishment of a database containing details of erosion and landslides that were known in the municipality, the production of a series of susceptibility maps, the development of guidelines and policy notes to deal with erosion and landslides, and recommendations for further investigations.

- Feltham (2005) mapped the incidence of erosion and landslides within the Corangamite CMA region, including the area around the Lake Connewarre Complex.

- Investigations undertaken for the Corangamite Soil Health Strategy (CCMA 2006) included an asset-threat modelling project that examined the risk to catchment assets (including those within the Lake Connewarre Complex) from various threatening soil processes such as erosion, landslides, waterlogging, acidification etc. (Dahlhaus & Clarkson 2006). The study concluded that the public assets within the Lake Connewarre Complex were threatened by soil erosion by water, secondary salinity, and the presence of potential acid sulfate soils. Private assets in the surrounding area were threatened by soil erosion by water and wind, soil nutrient decline, soil acidification, soil structure decline, soil waterlogging and soil contaminants.

- Research by Miner (2005a,b, 2007) extended the susceptibility mapping by GHD (2004a), their database of erosion and landslide incidents, and that established by Feltham (2005). The work was completed as part of the implementation of the Corangamite Soil Health Strategy, which aims at the insertion of an Erosion Management Overlay in the City of Geelong Planning Scheme.

Apart from the coastal rockfall hazard, landslides would not be expected in the planar landscapes of the Lake Connewarre Complex. Despite the relatively high rating for susceptibility of some of the soil-landform units (Table 4-3), there are very few incidents of erosion mapped in the Lake Connewarre Complex (Miner 2007).

### *4.2.2 Acid sulfate soils*

Potential acid sulfate soils often form in the waterlogged and highly reducing environments of coastal estuaries and mangrove swamps, where the conditions are ideal for the build-up of the iron sulfide mineral, pyrite ($FeS_2$). Such soils become strongly acidic (pH = <3.5) when disturbed and exposed to air (to become actual acid sulfate soils). On rewetting, the acid sulfate soils release acid and toxic elements which can kill fish, contaminate shellfish, pollute surface and groundwater and corrode concrete and steel infrastructure.

Three studies have recognised the potential for acid sulfate soils to develop in Lake Connewarre Complex.

- Primary Industries Research Victoria (PIRVic) undertook mapping of potential acid sulfate soils along the Victorian coastline at 1:100,000 scale (Rampant et al. 2003). The study estimated the extent of potential acid sulfate soils within the City of Greater Geelong as 11,745 ha, ranking it the second largest area in any Victorian municipality. The wetlands of the Lake Connewarre complex and much of the Moolap Lowlands were included.

- An investigation into the potential risk of acid sulfate soils for proposed development in the City of Greater Geelong was undertaken by CSIRO (Cox et al. 2005). This reconnaissance investigation involved a desktop assessment, general site inspections, and limited sampling and analysis. Three samples were taken at Reedy Lake. The report concluded that the area was a low risk as the municipal planning scheme already excludes from development the areas where potential acid sulfate soils exist (i.e. they are zoned for conservation use).

- A scoping study of coastal and inland acid sulfate soils in the Corangamite CMA was undertaken by CSIRO (Fitzpatrick et al. 2007) as background information for the Corangamite Soil Health Strategy (CCMA 2006). Soils were sampled from 29 sites, and 109 soil samples were characterised and 85 subjected to laboratory analyses. A number of samples were taken from Reedy Lake and Hospital Swamp. The soils of Reedy Lake, described as melacic sulfidic redoxic hydrosols, were rated as having a medium risk of developing acid sulfate soils if disturbed. The soils of Hospital Swamp, described as sulfidic redoxic hydrosols, were rated as having a high risk of developing acid sulfate soils if disturbed. The asset considered at highest risk was the aquatic biota.

### *4.3* Summary and Issues

1. The Lake Connewarre Complex is a geologically recent feature situated in the Moolap Lowland. Its ongoing geomorphic development is associated with the fluvial, lacustrine and estuarine processes of the Barwon River, the lakes and wetlands, and the tidal estuary.
2. Because of its landscape position at the edge of the Bellarine block and adjacent to the Mount Duneed volcanic plain, there are a variety of soil-landform units that have developed on the different landscapes around the complex. These soil-landform units are susceptible to a variety of land degradation processes if poorly managed.
3. The potential for acid sulfate soils to develop has been recognised in recent studies. The highest risk is to the aquatic environment if the soils are disturbed.

# 5 Sedimentation

Sedimentation in a coastal to near-coastal setting is a function of the following:

- sea level
- tectonics
- sediment supply.

To this list, Rosengren (1973) added human activities, which are an important determinant of sediment supply in the Lake Connewarre Complex.

Throughout the two-million-year duration of the Quaternary Period, the Earth's seas have been subject to repeated fluctuations in level due to an estimated 17 glaciations and subsequent interstadials. At the Last Glacial Maximum about 20,000 years ago, sea level was 120 m below the modern level. Following the last glaciation, sea level rose to 2 m above the current level at 6,000 BP (before present) (the mid-Holocene sea-level maximum) before falling slightly as the Earth's mantle adjusted to the redistribution of ice and water (Lambeck & Chappell 2001, Yu et al. 2007). The current rise in sea level of some tens of centimetres per century for the foreseeable future is a response to the probable warming of climate, as surface marine waters expand and water stored as ice is released from retreating glaciers and ice caps (IPCC 2007).

In the Bellarine-Surf Coast region, the sea-level changes are superimposed on older and presumably contemporary tectonic effects. Tectonic subsidence creates space for the accumulation and storage of sediment. The area beneath the Lake Connewarre Complex is likely to be subsident, with seismicity along an unnamed fault bearing NNE at the western limit of the Bellarine Peninsula providing evidence of continuing tectonism. Uplift to the east of this fault is responsible for the elevation of the Bellarine block. Volcanism is an additional tectonic process that has played a critical role in the character of the Lake Connewarre Complex (Coulsen 1935, Rosengren 1973, Cecil et al. 1988). Two lobes of a lava flow from Mt Duneed to the west abut the Bellarine block and have dammed the Barwon River at Lake Connewarre while a third determines where the Barwon meets the modern coast at Barwon Heads.

The main supply of sediment to the Lake Connewarre Complex is fluvial, from the Barwon River and its tributaries. Other possible sources (the elevated Bellarine block and marine sediment delivered on flood tides) appear to be negligible. Flood tides along with lacustrine processes play a significant role, however, in the reworking of fluvially supplied sediment.

## *5.1* Sedimentary character

Geologically young sediments beneath the Lake Connewarre Complex can be divided into three units that differ in age and, in part, in gross environment of deposition.

1. The oldest are marine sands, muds and shell beds that were deposited when the marine connection to the Lake Connewarre Complex was much stronger than now, probably during the mid-Holocene sea-level maximum. Gill & Lane (1985) reported a radiocarbon age of 3620 yr BP from an oyster shell from Campbell Point, Lake Connewarre, which they regarded as the approximate age of cessation of marine deposition in the lake. The fossils in this unit are identical in Lake Connewarre and at Reedy Lake, and indicate marine conditions in both in the mid-Holocene (Gill & Lane 1985).
2. The second unit represents the establishment of the Lake Connewarre Complex of fluvial, lacustrine and estuarine environments, and consists of mud and sand.
3. The most recent unit has been introduced since European settlement. It is similar to the second unit in being silts, clays and sands deposited in fluvial, lacustrine and estuarine environments. Except for a thin, brown oxic layer at the surface, sediment from within Lake Connewarre is grey-black and strongly oxygen-depleted (Longmore et al. 2004; see also

Sherwood et al. 1988). Unit 3 represents a marked increase in the rate of sediment supply to the Lake Connewarre Complex, particularly in the latter part of the 19th century and the beginning of the 20th century (Coulson 1935, Gill & Lane 1985). Small-scale sampling programmes by Billows (1998) and Bloink (2001) showed that surface sediment in the lower Barwon system contains a greater proportion of mud in areas of mangrove forests than adjacent unvegetated tidal flats, which are dominated by very fine- to medium-grained sand.

Units 2 and 3 have generally undergone intense mixing by organisms (*bioturbation* by plant roots and animal burrowing; Fabris et al. 2006) and are difficult to distinguish. They are the product of the Lake Connewarre Complex and are the focus of interest in this report whereas unit 1 predates the complex.

## *5.2* Sediment quality

We use the term, sediment quality, in reference to the occurrence or otherwise of contaminants in the sediment of the Lake Connewarre Complex. Very little information is available on this subject. Longmore et al. (2004) observed strongly elevated concentrations of mercury at about 15-25 cm below the sediment surface in a small number of cores taken from Lake Connewarre and related them to gold-mining in the Moorabool River catchment or to an unknown, now-defunct industry. They also detected enriched levels of phosphorus in the upper layers of sediments from two sites and suggested a recent introduction of a phosphorus-rich sediment source, which may be consistent with the increased application of artificial fertilisers over the past ~ 60 years.

Studies currently under way at Deakin University are designed to assess the occurrence of five toxic metals (arsenic, cadmium, copper, lead and mercury) in the sediment of the Lake Connewarre Complex.

## *5.3* Sedimentary process

A sedimentary process is the means by which sedimentary deposits are formed, modified or destroyed. It requires an agent, such as water, to act on sediment and thereby produce an effect. Three broad sedimentary processes operate within the Lake Connewarre Complex, deposition, erosion and transport.

### *5.3.1 Deposition*

Deposition takes place when the agent of sedimentary transport is no longer able to maintain sedimentary grains in motion. The character and rate of deposition differ from place to place within the Lake Connewarre Complex according to the local energy of the agent (water) and the distance from the river channel, among other factors. Stokes (2002) described as “aggressive” the sedimentation in the Lake Connewarre Complex since the mid-nineteenth century.

Deposition is responsible for several *constructive* landforms in the Lake Connewarre Complex and the lower Barwon River. These include:

- the tidal delta where Lake Connewarre meets the lower Barwon
- sandy beaches at the eastern shore of Lake Connewarre
- the saltmarsh and mangrove swamp surfaces
- levees along the river channel.

While the term, “tidal delta”, is used here for the landform, consisting of sand, shelly fragments and silt, at the junction of Lake Connewarre and the lower Barwon, Cecil et al. (1988) explicitly rejected a tidal role in its construction. Instead, they attributed the landform to constriction of the Barwon’s channel along this segment and resultant sedimentation on each side. Stokes (2002), though, following Rosengren (1973), concluded that the landform is indeed tidal, and that the delta has prograded (advanced) 1.5 km into Lake Connewarre from the lower Barwon since 1863. According to Stokes (2002), deposition upon the delta takes place during flood tide while scouring of channels within the delta is probably a phenomenon of the ebb tide. While accepting the landform as a tidal delta, Sherwood et al. (1988) inclined toward the suggestion that it is no longer accumulating sediment, an unlikely situation in light of Stokes's (2002) analysis.

Tidal flows are responsible for the supply of sediment to the saltmarsh and mangrove swamp surfaces, with deposition occurring near the peaks of the higher tides (Stokes 2002).

A quasi-delta at the junction of the upper Barwon River with Lake Connewarre exhibits some of the coarsest sedimentation (that is, a relatively high proportion of sand) in the Lake Connewarre Complex (Cecil et al. 1988). Sedimentation on the floor of Lake Connewarre, in contrast, is finer (mostly mud).

**Flocculation**, a process that is important in causing the sedimentation of clays which would otherwise remain in suspension, has been invoked to explain the general decrease in grain size of sediment across Lake Connewarre, away from the Barwon River (Longmore et al. 2004). Because clays bear an electrical charge, they may aggregate in a house-of-cards arrangement (flocculate). This behaviour is favoured by elevated salinities, such as those reached in the more northern and north-easterly parts of Lake Connewarre. On the other hand, sedimentation commonly shows an inverse relation between grain size and distance from source (in this context, the Barwon River) as the energy available for transport of sediment diminishes distally. The suggested role of flocculation remains speculative.

**Trapping** by vegetation, where mangroves or marsh plants slow the passage of sediment-transporting water, plays a significant role across much of the Lake Connewarre Complex (Rosengren 1973, Stokes 2002). Even more important is that, once sediment has been deposited, vegetation retains the sediment in place by the **binding** effect of its roots which resist erosion. Finally, the vegetation **modifies** the composition of the sediment by contributing organic matter to the sediment (Rosengren 1973). The effectiveness of vegetation in these roles may have changed in the last half century, as the abundance of mangroves in the lower Barwon River has increased markedly since 1947 (Stokes 2002). This may particularly be an effect of warmer (frost-free) winters in the last decade, in which case mangroves are likely to continue to proliferate in the next century.

### *5.3.2 Erosion*

Erosion is the removal of rock or sediment and is opposed to deposition. Nevertheless, many systems that are erosive are, at the same time, depositional, albeit in different places. In the Lake Connewarre Complex, erosion on the west-facing margins (Cecil et al. 1988) is complemented by deposition either on other parts of the margin or in deeper parts of the lake. Similarly, in the lower Barwon River, the migration of tidal channels is an effect of erosion on the outer sides of bends in the channels and deposition on the inner sides (point bars). Stokes (2002) observed that the lower Barwon River tidal system has an important role to play in minimising erosion in the event of future sea-level rises, since it acts as a physical buffer between the Lake Connewarre Complex and the sea by dissipating strong tidal currents and waves. Probably of more potential in the 21st century for causing erosion are the larger storm surges expected along the coast, a consequence of increased storminess (from a new report to the Victorian Government, *Infrastructure and Climate Change Risk Assessment for Victoria*: CSIRO, Maunsell Australia and Phillips Fox, which received prominence in *The Age*, 16th May 2007, but is not currently available). In this context, the lower Barwon River tidal system would play a similar buffering role.

Erosion is responsible for several *destructive* landforms in the Lake Connewarre Complex and the lower Barwon River. These include:

- channels, both fluvial and tidal (Cecil et al. 1988, Stokes 2002), and

- gullying associated with the lower breakwater where the Barwon River exits Lake Connewarre and which has been serious enough to threaten the integrity of the breakwater (Rosengren 1973).

The most effective agent of erosion in the Lake Connewarre Complex is water. Depending on the grain size, grain density and cohesion of the substrate, turbulence associated with currents and waves may be capable of entraining sediment. The most energetic flows are along the channels of the Barwon River and the lower Barwon River tidal complex. The outer sides of bends in the channels are particularly prone to erosion because this is where the flow from upstream meets the bank and is deflected around the bend. Complementary deposition takes place on the point bar at the inside of the bend. As a result of the two effects, there is an inherent tendency for channels to migrate laterally (Stokes 2002). In the case of tidal flows, flow competence is markedly asymmetrical when the high tide is high enough to flood the marshes (Stokes 2002); that is, the flood tide has a greater capacity to erode than the ebb tide. While vegetation is generally understood to stabilise sediment and promote sedimentation, it may also act to concentrate water flow along a single line and thereby promote the erosion of a single, dominant channel rather than the development of shallow braided channels (Tal & Paola 2007).

In some cases, energetic waves are capable of uprooting young plants in the Lake Connewarre Complex (Sherwood et al. 1988). Where this happens, the protection afforded by the vegetation is lost and erosion may follow.

Wind also plays a role in erosion in the Lake Connewarre Complex, though normally an indirect one. Wind drag, particularly on the lake waters, transfers energy to the waters which may be effective in eroding sediment, either from the shallow lake floor or the lake margins. This process is most consequential where the fetch (the width of the water body parallel to the wind direction) is greatest, as a long fetch permits a greater transfer of energy than a short one. At Lake Connewarre, the high incidence and the strength of south-westerly winds means that shoreline wave erosion is most intense on the eastern margin (Cecil et al. 1988). Turbidity in Lake Connewarre is greatest following winds which erode sediment from the lake floor and lift it into suspension (Sherwood et al. 1988). Such suspended sediment rapidly settles out again as calmer weather returns. High turbidity, when present, strongly inhibits the productivity of bottom-dwelling plants (Sherwood et al. 1988).

Another way in which wind may be significant is in the modification of the erosive potential of the tides on the Lake Connewarre Complex-lower Barwon. Onshore winds (south-westerlies and southerlies) cause higher tides, together with an earlier tidal peak. Storm surges may occur when strong onshore winds coincide with high spring tides (Stokes 2002). Offshore winds (northerlies) have a dampening effect.

Mass wastage in the form of slumping is important where sediment banks are steep. This is most common in association with channels in the lower Barwon River. Banks colonised by saltmarsh vegetation may be very steep or overhanging, especially where mangroves occupy the opposite bank (Stokes 2002).

An anthropogenic cause of erosion is power-boat use which Rosengren in 1973 linked to erosion in the lower Barwon River (refer also to Section 2.5.4).

### *5.3.3 Transport*

Sedimentary transport in the Lake Connewarre Complex is dominantly suspensive, though there is some bedload transport, especially in response to tidal movements in the lower Barwon River, and local mass movement in the form of slumping from oversteepened channel banks. Sediment enters the Lake Connewarre Complex from both ends: via the Barwon River as it flows from the hinterland and via the tidal system of the lower Barwon River. The low gradient of the Barwon above Reedy Lake ensures that it carries most of its sediment load in suspension. That is, most of the sediment influx from upstream is fine-grained (mostly silt; Cecil et al. 1988), though some sand may enter the complex as bedload (carried along the bed), especially during floods (Cecil et al.

1988). Bedload transport as a proportion of the total sediment load is likely to have diminished with the construction of two breakwaters across the floor of the channel. Higher tidal energies mean that bedload is probably a greater part of the sediment load entering the Lake Connewarre Complex from the lower Barwon River. In the cases of the sediment loads from both upstream and downstream, only a portion remains in the Lake Connewarre Complex as deposited sediment, with the rest continuing on, or returning, toward the sea. According to Cecil et al. (1988), sediment currently bypasses Reedy Lake because of the configuration of the Barwon channel at the entrance to Reedy Lake.

### 5.3.4 Environment

Sedimentary processes vary from place to place within the Lake Connewarre Complex because of variations in the configurations of the landforms present and the power of the various sedimentary agents. Pertinent variables are listed in Table 5-1. Processes may operate with a regular or semi-regular periodicity which varies according to the environment. Fluvial environments tend to be subject to strong seasonal variation in the supply of water, and to that can be added the rather poorly understood variation related to El Niño–Southern Oscillation (ENSO). Lacustrine environments may show seasonal variation in salinity and wind-related turbulence. The periodicity in tidal environments ranges from twice-daily (tides) to monthly (spring/neap tides) to annual (seasonal storminess).

| |
|---|
| subaerial exposure/inundation |
| water depth |
| distance from channel |
| position along channel (point bar, outer bend, reach) |
| salinity |
| tidal range |
| prevailing wind direction |
| wind variability |
| fetch |
| vegetation: mangrove |
| vegetation: saltmarsh plants |
| vegetation: lakefloor plants |
| construction of infrastructure |

*Table 5-1. Variables that influence the processes of sedimentation and erosion within the Lake Connewarre Complex.*

*partly after Stokes (2002).*

### 5.3.5 Rates

Especially important to understanding sedimentary processes is the question of rates. Longmore *et al*. (2004) sought to determine the rate of sedimentary accumulation at a number of points within Lake Connewarre from the first appearance of the pollen of exotic pine (*Pinus*) and the peak occurrences of mercury (heavily used in the extraction of gold during the 19th century gold rushes). On this basis, Longmore et al. (2004) concluded sedimentation on the floor of Lake Connewarre averaged 1.5 mm $y^{-1}$ for the past 70-110 years. The usefulness of this figure is questionable, however, unless it applies to the shorter span of 70 years. Coulsen's observations of 1935 allow us to recognise a pre-1935 period of much higher sedimentation rates than post-1935 (see Cecil et al. 1988). From 1861 to 1935, the middle of Lake Connewarre became shallower by three feet (one metre) at a rate of 13 mm $y^{-1}$, whereas current rates are much less. It is likely that the higher rates of sedimentation are due to the historical mining and industrial causes discussed in Section 2.

In a longer timeframe, deposition has been more rapid in Reedy Lake than in Lake Connewarre (Cecil et al. 1988). This is despite the negligible sedimentation in Reedy Lake today (Cecil et al. 1988). Gill & Lane (1985) inferred virtually identical marine environments in the two areas at the time of the mid-Holocene highstand in sea level (6,000 - 3,600 BP), which suggest nearly equal depths of inundation. The basalt lobe at Tait's Point acts as a local base level which controls sedimentation in Reedy Lake (see Cecil et al. 1988). Today, Reedy Lake is a marsh whereas Lake Connewarre remains lacustrine.

### *5.4* Sedimentary sources

The Corangamite Catchment Management Authority has sought answers to the question, 'What are the major sources of the sediment that has accumulated in the Lake Connewarre Complex in the last 150 years?' Longmore et al. (2004) used the high incidence of mercury in parts of unit 3 to suggest an increased contribution of sediment from the Moorabool River catchment, where mercury was used in the recovery of gold for many years. Longmore et al. (2004) did not explain why elevated mercury transport from the Moorabool means that the proportional contribution of siliciclastic sediment from the Moorabool catchment also must have increased. Nor do they explain why mercury is not derived from the Leigh River catchment, which includes the much bigger gold-mining area of Ballarat (refer to section 2.3.2).

More convincing is the analysis by Fabris et al. (2006) who used a very wide range of geochemical species in combination with statistical modelling to estimate the contributions of four possible sources to the sediments in unit 3. They concluded that over 50% of the sediment comes from the Moorabool River catchment, under 25% from the Barwon River catchment, about 15% from the Leigh River catchment and 5% from the environs of the Lake Connewarre Complex. The heavy input from the Moorabool River is explicable in that the Moorabool has a steep gradient even in its lower reaches and, hence, may have the competence required for the transport of the bulk of the sediment deposited in the complex.

### *5.5* Predictions

Cecil et al. (1988) made the following predictions in regard to sedimentation within the Lake Connewarre Complex under four different scenarios.

1. With no change in river flows, deposition of a predominantly suspended sediment load would continue, and the lake basins would gradually fill. No timescale is given but they state that it would occur "over a much greater timespan" than described for the present lake system.
2. With a reduction in the flood peak as usually experienced in winter-spring, the delivery of coarse sediment would decline. There would be reduced flushing of the lake complex with increased opportunity for suspended sediment to settle out, and sediment would aggrade more rapidly.
3. With higher baseflows, the proportion of coarse sediment in the sediment load would rise. The channel across the lake complex from the upper Barwon to the lower Barwon would become well defined with the development of levees. As a consequence, Lake Connewarre would become detached and would develop into an aggrading brackish marsh. The general rate of sedimentation would be much more rapid than at present.
4. With significantly lower baseflows, sedimentation would be slower than now. The incidence and rate of erosion within the system would rise with the loss of bank vegetation as the reduced freshwater input results in more saline conditions.

### *5.6* Management

Sherwood et al. (1988) emphasised the inherent dynamism of the estuarine environment of Lake Connewarre and the Lower Barwon River. This means that natural river flows should not be inhibited from continuing to influence the Lake Connewarre Complex, notably in the form of flushing during peak floods. The dynamic water regime implies a dynamic sedimentary regime. That is, localised sedimentary deposition, erosion and transport are all to be expected and planned for. Where changes occur as a result of human endeavours or natural processes, the behaviour of the agents of deposition, erosion and transport will change and so too will the patterns of deposition, erosion and transport.

The role of the lower Barwon tidal complex in protecting the Lake Connewarre Complex from marine erosion was placed in the context of rising sea level by Stokes (2002). She concluded that friction in the system of tidal creeks dissipates the energy of tidal currents and waves which may be very strong at the coast. Modification of the tidal complex may lead to its degradation and the consequent exposure of the Lake Connewarre Complex to higher energies, particularly as sea level rises, and, hence, to increased erosion.

### *5.7* Summary and issues

The major external controls on sedimentation in the Lake Connewarre Complex are sea level, tectonics, sediment supply and human activities. Intrinsic to the complex are sedimentary characteristics associated with each of the environments present, namely, fluvial, lacustrine and estuarine environments. The sediment supply of predominant silt from the Barwon River system, supplemented by minor sand from the river, the sea and the Bellarine high, is distributed through the Lake Connewarre Complex by a range of processes which are typical of the environments present. The extrinsic process of sea-level rise following the last glaciation led to the replacement of a seaway connecting Corio Bay to Bass Strait by the evolving Lake Connewarre Complex of non-marine and marginal-marine sedimentation. Small lakes like those of the Lake Connewarre Complex are ephemeral on geological timescales. If the external controls were to remain constant, the lakes of the complex would fill with sediment and become part of a floodplain, similar to the Belmont Common, over perhaps some tens of thousands of years.

The extrinsic processes, however, do not remain constant. The impact of human activities on sediment supply to the Lake Connewarre Complex has long been known in the form of substantial shallowing of Lake Connewarre as mining and industrial waste has been transported from distant and local sources. A pervasive human influence on global climate is now generally acknowledged and will tend to higher sea levels whose effects are exacerbated by increased storminess. The protective barrier system at Barwon Heads will be of growing importance in insulating the Lake Connewarre Complex from increasing marine energies.

The leader of the team from the CSIRO that co-authored a new report to the Victorian Government on the effects of climate change on Victoria made the observation: "We have to plan as if we'll be living in a different country" (*The Age*, 16th May 2007). Sedimentation in the Lake Connewarre Complex will be subject to change as the external controls influence the internal processes of the system.

The following issues emerge from the review of sedimentation:

- The effect of climate change is predicted to lead to reduced river flows (e.g. Cai & Whetton 2001) and therefore reduced sedimentation within the Lake Connewarre Complex (Cecil et al. 1988 suggested that shallowing of Lake Connewarre would slow).
- Human engineering and recreational activities within the Lake Connewarre-Lower Barwon system will alter the patterns of sedimentary deposition, transport and erosion.
- There is virtually total ignorance of the quality (i.e. levels of contaminants) of the sediments in the Lake Connewarre Complex that have been deposited since European settlement (this in light of the history of heavily polluting industries along the Barwon River at Geelong and the mining in the Central Highlands).

# 6 Hydrogeology

This section covers only the hydrogeology, or groundwater hydrology. An extensive review of the literature or reports on surface water hydrology is beyond the scope of this project, and surface water hydrology is discussed only where relevant to the groundwater interactions. A review of literature related to environmental flows and surface water quality follows (refer to Section 9).

## *6.1* Regional Hydrogeology

The regional hydrogeology of the Bellarine Peninsula is poorly understood in comparison to other landscapes in the Corangamite region. This results partly from the fact that there are comparatively few aquifers which are currently being exploited for groundwater resources and, therefore, little investigation undertaken.

On the Bellarine Peninsula, the earliest documented references to groundwater are those associated with the mineral springs on the northern side of the Bellarine Peninsula, especially around Clifton Springs where up to one megalitre of groundwater per week discharges from joints in the Older Volcanics and Fyansford Formation (Shugg 2004). Richard Daintree, a government geologist who geologically mapped parts of the Bellarine Peninsula in the early 1860s, recorded several groundwater wells on his maps (Table 6-1), but no data on water depth or quality were presented.

| **Sheet** | **Name** | **Year** | **Feature** | **Observation *[annotated by Daintree]*** |
|---|---|---|---|---|
| 23 NE | Portarlington | 1861 | Spring | on shoreline |
| 23 SE | Drysdale | 1861 | Waterhole | in township of St Leonards |
| | | | Waterhole | in township of St Leonards |
| 23 SW | Moolap | 1860 | Springs | on shoreline (Clifton Springs) |
| | | | Springs | on shoreline (Clifton Springs) |
| | | | Waterhole | |
| | | | Waterhole | *6ft deep in stiff brown clay with concretionary nodules of limestone* |
| | | | Waterhole | *1ft ironstone pebbles, 6ft yellow clay* |
| | | | Waterhole | *6ft deep in brown marl with interbedded nodules of hard argillaceous limestone* |
| | | | Waterhole | *in brown marl with interbedded nodules of limestone* |
| 28 NE | Mt Duneed | 1861 | Waterhole | *in yellow clay* |
| | | | Waterhole | *in hard brown sandstone* |
| | | | Waterhole | *8ft deep in yellow clay* |
| | | | Waterhole | *in hard brown sandstone* |
| | | | Waterhole | *4ft fine grained quartz pebble drift, 1ft brown sandstone* |
| | | | Waterhole | *10ft through red and brown mottled clays* |
| 29 NE | Queenscliff | 1861 | Well | in Queenscliff township |
| | | | Well | in Queenscliff township |
| | | | Waterhole | on the shore of Swan Bay |
| 29 NW | Lake Connewarre | 1860 | Well | in Barwon Heads, near the Barwon River estuary |
| | | | Well | in Barwon Heads, near the Barwon River estuary |
| | | | Well | adjacent to a marsh |
| 29 SW | Breamlea | 1861 | Well | *Buckley's well* near Thompson Creek |

*Table 6-1. Groundwater features recorded on the early geological maps.*

From the mid-1950s, systematic hydrogeological investigations were undertaken by the Geological Survey of Victoria (Esplan 1956, 1962; Medwell 1957, 1958). The surveys were initiated by the desire to secure a water supply for St. Leonards and Indented Heads, but the exploration proved futile. Bores were sunk to over 170 m depth, but it was concluded that potable water suitable and sufficient for a town water supply was unavailable from any of the shallow or deep aquifers.

More recent reviews include the regional descriptions of the hydrogeology completed by Leonard (1979, 1992) and Dahlhaus et al. (2002), and student reports by Jerinic (1992), Dixon (1996) and Mockunas (2006). A number of site-specific, intensive hydrogeological studies have also been undertaken, such as those at Point Henry (for Alcoa) and The Dell (for City of Greater Geelong).

Summarised from these various reports, the hydrogeological units (aquifers) of the Bellarine Peninsula comprise:

### Otway Group

The fractured sandstones and mudstones of the Otway Group form the basement aquifer of the Bellarine Peninsula. As there is no known extraction of groundwater from this aquifer, data on the aquifer parameters or water quality are not available. Most of the aquifer is confined by the overlying strata and is recharged via the outcrop of Otway Group rocks along the higher ground around Drysdale.

### Eastern View Formation / Werribee Formation

The Eastern View Formation is found at depths of around 700 m east of the Bellarine Fault in the Sorrento Graben (Holdgate et al. 2002) and about 120 m below the Moolap Sunklands. The aquifer thickness ranges from 60 to 100 m and comprises quartz gravels and sandstones. Yields are generally low, ranging from 0.5 to 5 litres per second, and the quality varies from 1500 mg $l^{-1}$ to 3000 mg $l^{-1}$ total dissolved solids (TDS). The Werribee Formation is listed as one of the deeper aquifers at The Dell (D'Andrea 2003) but little information is provided. Its distribution is probably limited to north of the Curlewis Monocline.

### Older Volcanics

The fractured basalt of the Older Volcanics crops out on Mt Bellarine, where it comprises an unconfined aquifer. East of the Bellarine block (Swan Bay) the Older Volcanics are intercalated with the Eastern View Formation (124 m depth) and the Fyansford Formation (at 44 m depth), and form a confined aquifer. The Older Volcanics are exposed on the shore platform below The Dell, near Clifton Springs, where they discharge mineralised, effervescent springwaters, probably recharged via the outcrop on the Bellarine block. Bore yields are generally less than 5 l $s^{-1}$, and quality ranges from 1500 mg $l^{-1}$ to 3000 mg $l^{-1}$ TDS, with the freshest waters in the areas of higher recharge.

### Fyansford Formation

The limestones and marls of the Fyansford Formation overlie the Eastern View Formation beneath the Moolap Lowland and are more extensive east of the Bellarine block, where they reach a thickness of 120 m. Bore yields are generally less than 5 l $s^{-1}$ and salinities range from 3000 mg $l^{-1}$ to 7000 mg $l^{-1}$ TDS, although up to 14,000 mg $l^{-1}$ was measured at The Dell (D'Andrea 2003).

### Moorabool Viaduct Formation / Pliocene Sands

Siliceous, calcareous and ferruginous gravels, sands, silts and clay of the Moorabool Viaduct Formation are the most widespread unconfined aquifer on the Bellarine Peninsula. Thickness varies from less than 1 m to 30 m east of the Bellarine Fault. The average thickness is probably less than 15 m. Water quality varies considerably probably due to the length of the groundwater flow path (long flow paths accumulate more salt). Some low-salinity (<1000 mg $l^{-1}$ TDS) water is reported, but most is in the range 3000-7000 mg $l^{-1}$. Bore yields are reasonable, although generally less than 5 l $s^{-1}$.

**Newer Volcanics**

The fractured basalts and porous pyroclastic rocks of the Newer Volcanics comprise an unconfined aquifer on the north-western and south-western side of the Bellarine Peninsula. Very few bores exploit the groundwater in the Newer Volcanics aquifer, as it is reasonably saline. Those nearest the Lake Connewarre Complex are quite saline (9,290 and 11,203 mg $l^{-1}$ TDS) and others in the Mt Duneed volcanics are also in the range of 6,000 to 9,000 mg $l^{-1}$ TDS (Dahlhaus et al. 2004). In the north-western flows, the basalts are largely unexploited for groundwater, since they occur in the urban environment and are possibly unsuited to urban use (no data available).

**Quaternary sediments**

The groundwaters of the various Quaternary sediments vary according to the type of sediment, their geological evolution and their current landscape setting. Estuarine sediment aquifers are often connected to marine waters, whereas the unconfined shallow aquifers comprising alluvial sediments adjoining the Barwon River are often connected to the surface water flows in the river. Swamp and lagoonal deposits have similar variations.

## *6.2* Hydrogeology of the Lake Connewarre Complex

The hydrogeology of the Lake Connewarre Complex is poorly understood. Despite an extensive search, no published studies of the hydrogeology of the Lake Connewarre Complex were found, and very few unpublished studies, investigations or research reports were located. The Corangamite Groundwater Monitoring and Research Database (Dahlhaus et al. 2004), which compiles all documented bores in the region, records 39 groundwater bores in the wider area (Table 6-2, Figure 6-1). The majority are located in and around Ocean Grove and Barwon Heads and are registered for domestic use and stock watering. Note that the listed bores do not include those that may have been constructed recently due to the current drought, as the records are not yet available on the water data website (http://www.vicwaterdata.net/vicwaterdata/home.aspx).

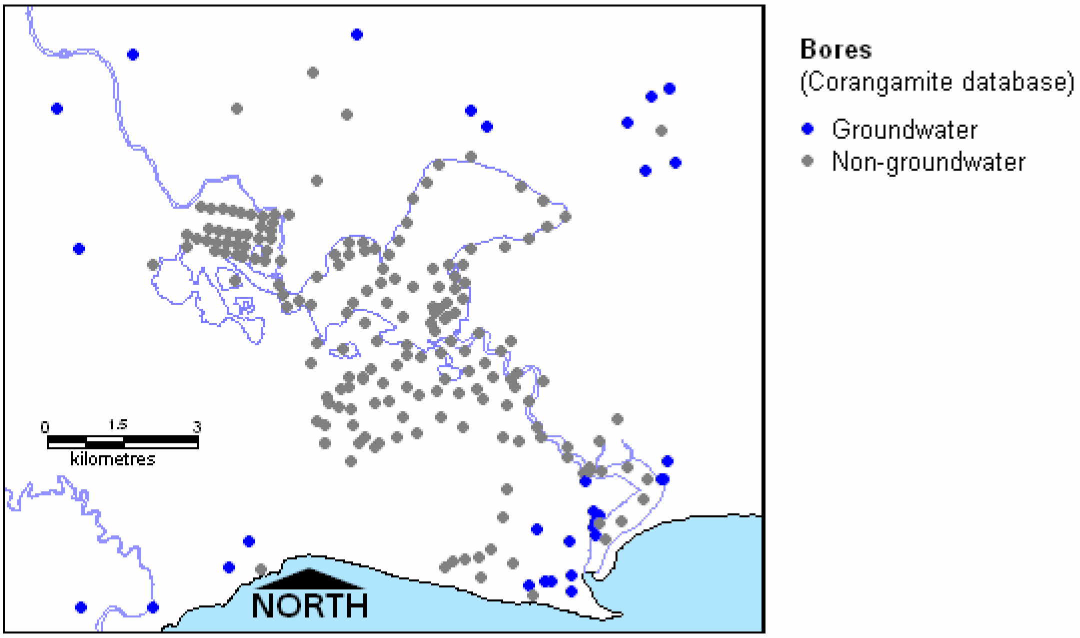


*Figure 6-1 Groundwater and other bores in the Lake Connewarre Complex area.*

| Bore | Owner | Year | Depth (metres) | Use | TDS (mg/L) |
|---|---|---|---|---|---|
| 80114 | Dept of Mines | 1927 | 103.32 | Domestic and stock watering | |
| 88787 | Private landholder | 1970 | 15.24 | Domestic and stock watering | |
| 80116 | Private landholder | 1977 | 75.12 | Domestic and stock watering | |
| 56377 | Private landholder | 1982 | 13 | Domestic | 1,345 |
| 56378 | Private landholder | 1982 | 18 | Domestic and stock watering | 11,203 |
| 56384 | Private landholder | 1982 | 6.1 | Domestic | 2,304 |
| 56385 | Private landholder | 1982 | 12.19 | Domestic | |
| 48859 | Private landholder | 1983 | 16 | Not Known | 12,183 |
| 48866 | Private landholder | 1983 | 18.5 | Not Known | |
| 48869 | Private landholder | 1983 | 3 | Domestic | 3,456 |
| 48870 | Private landholder | 1983 | 2.74 | Domestic | 746 |
| 48874 | Private landholder | 1983 | 3 | Not Known | |
| 56381 | Private landholder | 1983 | 52.46 | Not Known | |
| 56382 | Private landholder | 1983 | 14 | Irrigation | 2,486 |
| 56383 | Private landholder | 1983 | 2.45 | Domestic | 580 |
| 56386 | Private landholder | 1983 | 6.1 | Domestic | 800 |
| 56387 | Private landholder | 1983 | 20.22 | Irrigation | 2,680 |
| 56389 | Private landholder | 1983 | 3 | Domestic | |
| 56390 | Private landholder | 1983 | 3 | Domestic | |
| 56388 | Private landholder | 1985 | 66.22 | Not Known | 3,120 |
| 56391 | Private landholder | 1985 | 10.2 | Not Known | |
| 56392 | Private landholder | 1985 | 10.2 | Not Known | |
| 56394 | Private landholder | 1985 | 6.1 | Investigation | |
| 80123 | Private landholder | 1986 | 3 | Domestic and stock watering | |
| 56395 | Private landholder | 1990 | 14 | Domestic | 9,260 |
| 134240 | Not known | 1998 | 18 | Investigation | |
| 134243 | Not known | 1998 | 24 | Investigation | |
| 135908 | Not known | 1998 | 39 | Stock watering | |
| 141862 | Not known | 1998 | 48 | Domestic and stock watering | |
| 142238 | Not known | 2000 | 7 | Domestic | |
| 142265 | Not known | 2000 | 12 | Domestic | |
| 142308 | Not known | 2000 | 30 | Domestic | |
| 142336 | Not known | 2000 | 57 | Stock watering | |
| 142385 | Not known | 2000 | 42 | Irrigation | |
| Reedy 1 | Parks Victoria | 2006 | 3.05 | Monitoring and research | ~10,000 |
| Reedy 2 | Parks Victoria | 2006 | 3.05 | Monitoring and research | ~12,000 |
| Reedy 3 | Parks Victoria | 2006 | 3.55 | Monitoring and research | ~35,000 |
| Reedy 4 | Parks Victoria | 2006 | 1.50 | Monitoring and research | ~17,000 |
| Reedy 6 | Parks Victoria | 2006 | 2.75 | Monitoring and research | ~2,000 |

*Table 6-2 Groundwater bores listed in the Lake Connewarre environs.*

*(Source: Corangamite Groundwater Monitoring and Research Database, Dahlhaus et al. 2004)*

Two studies are currently under way which will assist in developing an understanding of the hydrogeology of the Lake Connewarre Complex. CSIRO is conducting research on groundwater-dependent ecosystems in the Corangamite CMA region (Barton et al. 2006a,b,c,d, 2007a). While the lakes and wetlands of the Lake Connewarre Complex are included, it is not one of their target systems for more intensive investigations. The second study is an on-going low-level research project on the groundwater–surface water interactions of Reedy Lake, being undertaken by the University of Ballarat (Mockunas 2006; Dahlhaus, unpublished data).

## 6.3 Reedy Lake groundwater study

Within the study area, the only known hydrogeological investigation has been undertaken as part of a recent and on-going study of the groundwater-lake water interactions at Reedy Lake. The study was initiated in response to an initial assessment that the surface water–groundwater interaction was important to the wetland ecosystem (Environmental Flows Technical Panel 2006). In particular, it was believed that groundwater salinity is critical to the health and distribution of reeds. Commencing in 2006, the hydrogeological investigation aimed at providing information on the:

- groundwater system(s) at the site
- groundwater chemistry and the horizontal and vertical variations in salinity
- relationship of the groundwater to plant communities
- effect of surface water management on groundwater levels and salinity
- management of surface water to manipulate vegetation communities

*(Ecological Associates 2006).*

Four bores were drilled in Reedy Lake and two in Hospital Swamp when the lakes were drained. Five of these bores (four in Reedy Lake and one at Hospital Swamp) were constructed as monitoring piezometers (Miner 2006a). The water levels of the groundwater, lake and river are monitored on a monthly basis by members of the Geelong Field and Game Association. The groundwater in the bores has also been sampled on three occasions by the University of Ballarat and the samples analysed by CSIRO, Adelaide (Mockunas 2006, Barton et al. 2006e; Dahlhaus, unpublished data).

The stratigraphy at Reedy Lake is relatively simple. The veneer of unconsolidated lake sediments comprises an unconfined aquifer generally less than two or three metres thick which rests on a highly plastic clay, probably the Fyansford Formation (Miner 2006a), which acts as an aquitard. The lake sediments are spatially variable in their composition but generally consist of lake-floor dark brown clayey silt underlain by silty, shelly sands, which are underlain by dark grey to black silt.

Hydraulic conductivity measurements from single bore recovery tests varied from 0.6 to 0.08 m $d^{-1}$ (Mockunas 2006). A much greater value is indicated in at least one bore which yielded 0.12 l $s^{-1}$. It is likely from the descriptions of lake sediments (Coulson 1935, Miner 2006a Section 5.1) that the hydraulic conductivity will vary by orders of magnitude and be anisotropic and heterogeneous at the local scale.

The salinity of the groundwater contained in the lake sediments aquifer is highly variable and, as yet, the variation is unexplained. The chemistry shows that the groundwaters of the lake are very similar, being mostly sodium-chloride or sodium-magnesium-chloride types. Closer to the river at the upstream end of the lake, the groundwater is sodium-chloride-bicarbonate type, indicating a strong meteoric influence. The composition of the stable isotopes of oxygen and hydrogen indicate that the groundwater in the centre of the lake and the surface water system mix very little. However the groundwater closer to the river shows a stronger connection to the Barwon. Similarly the samples from a bore downstream of the barrage and closer to Lake Connewarre indicate that the groundwater system at that location may be weakly connected to the marine water system. These variations in salinity and isotopic composition indicate that the interaction of surface water from the lake, river and sea with the groundwater is complex (Mockunas 2006).

## *6.4* Summary and Issues.

1. In comparison to many other lakes in the Corangamite region, the hydrogeology of the Lake Connewarre Complex is very poorly understood, since there has been little research and investigation undertaken to date. Several groundwater flow systems and aquifers are mapped in the region. Around the Lake Connewarre Complex study area these include the Quaternary sediments, Newer Volcanics, Moorabool Viaduct Formation, and Fyansford Formation. Information on the interaction of the groundwater between the different aquifers in this area is unavailable.
2. The small-scale research project at Reedy Lake indicates that there are complex interactions between surface waters, groundwaters and marine waters. The groundwater–surface water interaction at Reedy Lake is thought to be a strong influence on the distribution and health of the vegetation communities, which correspondingly impact on the lake ecosystem.
3. The interactions between the various hydrological systems have been and continue to be modified by anthropogenic intervention such as the construction of tidal barrages, connecting channels, and drains. The present understanding of the surface water–groundwater interactions is extremely poor, although it has been shown to be complex, and therefore the effects of modifications to the surface water hydrology on the ecosystem health cannot be predicted.
4. Groundwater discharge influences the quantity and quality of water in the Lake Connewarre Complex’s ecosystems, although the degree of dependence on local, intermediate and regional groundwater systems is, as yet, unknown. Changes to the groundwater systems (either anthropogenic or natural) could have long-term impacts on ecosystem health and may not be apparent for some time. Examples include altering groundwater recharge rates through urban or agricultural developments, altering the rates of groundwater discharge by constructing channels or deepening lakes, and changing water quality through urban or agricultural development.

# 7 Flora

> *"The portion of the district … between the Barwon River or Lake Connewarre and Clifton Springs, yields a vegetation highly interesting in itself, and far more varied in character than at first sight might be supposed, and is remarkable for its variety of shrubs and herbaceous plants, than for its trees. … But it is to be feared and regretted that many species of herbs and annuals which at present adorn the hillsides and valleys of the locality, may in the course of a few years disappear, owing to the pasturage of stock."*
>
> *(W.R. Guilfoyle 1894)*

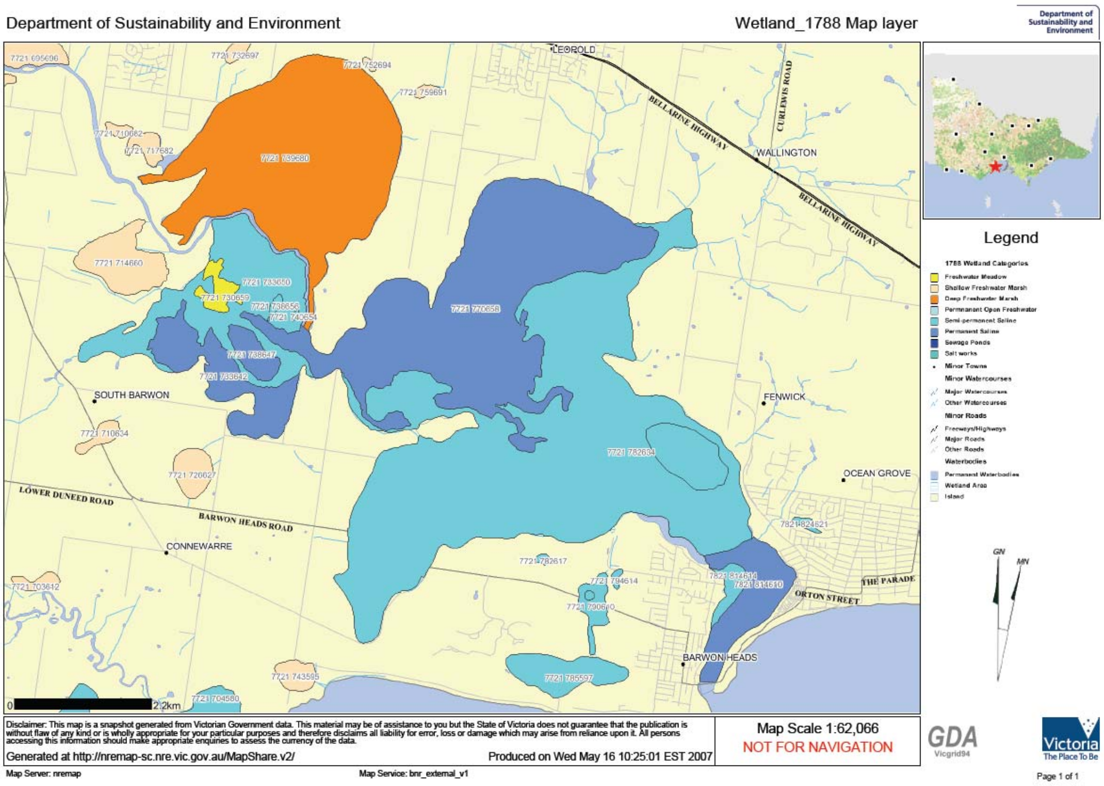
This early account of the flora of the Bellarine district by Guilfoyle (1894) gives an indication of the type of terrestrial vegetation that would have been encountered around the northern and eastern shores of the Lake Connewarre Complex during that period, as well as a brief mention of some of the wetland plants. The author's fears of the loss of the local plant diversity have been vindicated as the tracts of land surrounding the wetlands have been cleared for farming and rural residential development (Department of Sustainability and Environment 2003a).

The Lake Connewarre State Game Reserve (which approximates the Lake Connewarre Complex) occupies an area of 3411 ha (Department of Conservation and Natural Resources 1993) and is the largest area of native vegetation on the Bellarine Peninsula. This area is characterised by wet coastal complex vegetation on saline soils with sharp zonal boundaries between structural forms and plant assemblages (Department of Conservation and Natural Resources 1993, after Land Conservation Council 1985). The wetlands complex consists of an extensive estuarine and saltmarsh system drained by the Barwon River that supports a wide variety of wetland habitats (Australian Nature Conservation Agency 1996). These include a large, shallow estuarine lagoon (Lake Connewarre; Rosengren 1973), a deep freshwater marsh (Reedy Lake), several semi-permanent saline wetlands, and an estuary (Australian Nature Conservation Agency 1996).

The Victorian Wetland Database map layers, 'Wetland_1788 layer' and 'Wetland_1994 layer' (Department of Conservation and Natural Resources 1995), provide mapping data, including extent and wetland type, of Victorian wetlands prior to European settlement and up to 1994, respectively. Comparison of these two mapping layers allows for the approximate determination of changes in wetland type and extent within the Lake Connewarre Complex. Figure 7-1 shows the changes in wetland type and extent between 1788 and 1994.

The vegetation of Victoria has been classified and mapped into distinct Ecological Vegetation Classes (EVCs). The EVC data layers of the Lake Connewarre Complex represent the current and pre-European vegetation of the area. The bioregional conservation status of each mapped unit is also represented in a separate layer. These and other mapping data are available to the public via the internet through the Victorian Department of Sustainability and Environment's website (www.dse.vic.gov.au) using its interactive mapping facility. Twelve EVC's are mapped within the Lake Connewarre Complex. Four EVCs are rated as endangered within the the Otway Plain Bioregion, five as vulnerable, one as rare and one as depleted. Table 7-1 lists the current EVCs identified within the Lake Connewarre Complex and their corresponding bioregional conservation status as shown on the Biodiversity Interactive Maps (Department of Sustainability and Environment [online] 21/6/2007).

One of the earliest descriptions of vegetation within and around the Lake Connewarre Complex is that of John Helder Wedge in 1835 (in Rowe 2002). He described the area around the lake system as being of "fine grassy open plains" with inland grassy rises that were "thinly timbered" on light soils. He also made mention of the "fine marshes" of the area.



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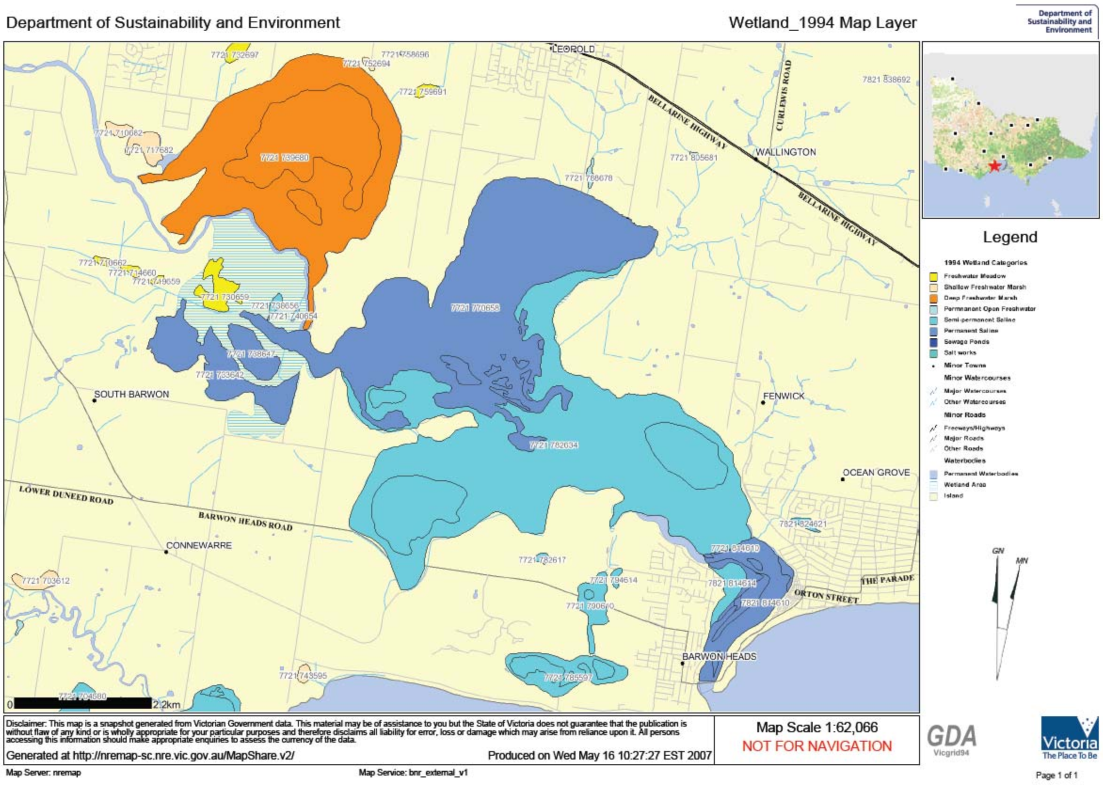

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*Figure 7-1 Extent and types of wetlands within the Lake Connewarre Complex for the years 1788 and 1994.*

| EVC No. | Ecological Vegetation Class (EVC) | Conservation Status |
|---|---|---|
| 1 | Coastal Dune Scrub/ Coastal Dune Grassland Mosaic | Depleted |
| 132 | Plains Grassland | Endangered |
| 140 | Mangrove Shrubland | Vulnerable |
| 175 | Grassy Woodland | Endangered |
| 196 | Seasonally Inundated Subsaline Herbland | Rare |
| 300 | Reed Swamp | Vulnerable |
| 302 | Coastal Saltmarsh/ Mangrove Shrubland Mosaic | Endangered |
| 858 | Coastal Alkaline Scrub | Endangered |
| 891 | Plains Brackish Sedge Wetland | Vulnerable |
| 898 | Canegrass Lignum Halophytic Herbland | Vulnerable |
| 899 | Plains Freshwater Sedge Wetland | Vulnerable |
| 992 | Water Body — Fresh | Not Applicable |

*Table 7-1 Ecological Vegetation Classes identified and mapped within the Lake Connewarre Complex*

In 1855, a letter written by assistant surveyor, John Hamlet Taylor, was tabled at a meeting of "the Council" by the Surveyor General, Captain A. Clarke, R.E. (17th April, 1855). It referred to the survey of the "River Barwon" by Mr Wills for the purposes of selecting the most suitable position to build a breakwater (PROV, VPRS 44, Unit 470). The vegetation within the lake was described as follows:

> *A great portion of the lakes is covered with floating vrack* (sic)*, and the bed of the lake is chiefly covered with sea weed and sea grass.*

Taylor described the surrounding area as:

> *swamps … covered with samphire and polygonum scrubs (the latter most likely being Tangled Lignum Muelenbeckia florulenta), upon black, soft mud, impregnated with salt, and the marshes covered with tussec* (sic) *grass upon stiff, clay soils.*

The most comprehensive investigation of the flora of the Lake Connewarre Complex was conducted by Yugovic (1985). His work provides a detailed account of the vegetation structure and floristics within the Lake Connewarre State Game Reserve (LCSGR) based on field surveys carried out from September to December 1983. The report identifies and describes 15 vegetation map units (VMUs) reflecting floristically distinct plant "associations", or "sub-communities", revealed by the analysis of 87 100 $m^2$ (10 m x 10 m) quadrats throughout the reserve. The information collected for each VMU includes:

- the percent frequency of occurrence and mean cover abundance of the major component species;
- the degree of distribution and general locations of the VMU;
- the area in hectares and as a percentage of the total area of the LCSGR;
- the substrate type;
- the type of vegetation structure;
- the mean floristic richness (as the mean number of species per site);
- the mean weed composition (as a percentage of species and percentage of cover);

- the number of sites surveyed;
- a description of unit characteristics; and
- a rating of the VMU's susceptibility to disturbance (on a scale of low to moderate to high).

Yugovic (1985) identified and recorded 137 native and 78 exotic vascular plants, of which 18 were considered to be of conservation significance at the time of publication. These included terrestrial and wetland species.

The distribution of all VMUs was presented on a scaled map. Such detailed information is valuable as a starting point for mapping temporal changes to the wetlands' vegetation and may assist in explaining the processes that effect these changes. An investigation by Ecological Associates Pty Ltd (2006) into the effects of groundwater on the distribution and health of plant communities in Reedy Lake used Yugovic's maps as a baseline for measuring vegetation changes in the lake over a twenty-year period. The report suggested that the combined effects of groundwater salinity and flooding history are reflected in the distribution of plant communities and that the spread of *Typha* and *Phragmites* may be due to a "freshening of the system". The reduction of groundwater salinity was thought to be a combination of processes, including the construction of the lower breakwater, exclusion of tidal inflows from the lake (understood to mean Lake Connewarre), the creation of permanent freshwater inflows and the permanent storage of water in the lake (understood to mean Reedy Lake).

Yugovic also provided descriptions of six distinguishable sectors of the LCSGR, which form discrete, recognisable physical units. They include:

1. The lower estuary of the Barwon River (downstream of the tidal delta at the exit of Lake Connewarre);
2. Murtnagurt Swamp (a semi-isolated saltmarsh south-west of Barwon heads);
3. Salt Swamp (a 460 ha expanse of saltmarsh north of the Geelong-Barwon Heads Road);
4. Lake Connewarre (a shallow estuarine lagoon);
5. Hospital Swamp (in the southwest of the reserve); and
6. Reedy Lake (the largest freshwater wetland in central Victoria)

Yugovic's (1985) study also addressed the conservation significance of each sector and wetland type (based on Corrick's 1982 classification of Victorian Wetlands). He commented on the habitat value of the wetlands system in terms of avifauna, but did not raise the importance of this habitat for other vertebrate or invertebrate groups.

Yugovic identified four issues relating to the management of the reserve's vegetation. These included grazing by domestic livestock, the manipulation of hydrology via engineering works, and the impacts of recreational use and invasion of weed species.

## *7.1* Saltmarsh

Coulson (1933) appears to be the first to recognise zonation patterns within the saltmarshes of the Lake Connewarre system. He commented, "As the mud-banks build themselves higher above water level, they exhibit a floristic sequence of very interesting character." He observed that the group of samphire glasswort, sea blite, and water buttons occupied the lower marsh, followed by swamp weed, common orache, sea celery, slender celery, common sea heath, streaked arrow-grass, creeping brookweed and finally salt grass, shrub aster, pale goosefoot, seaberry saltbush, thatch sedge (more likely chaffy saw sedge, *Gahnia filum*) and barley grass at higher elevations.

Barson (1976), in her account of tidal salt marshes in Victoria, pointed out that Victoria's coastal saltmarshes are best developed between Barwon Heads and Corner Inlet. She also noted that sea heath (*Frankenia pauciflora*) and *Wilsonia* species are two plants with very limited distributions in Victorian salt marshes. Both these genera are common within the Lake Connewarre Complex. An extensive area of herbland at Salt Swamp, consisting solely of Victoria's three *Wilsonia* species (*W. humilis, W. backhousei* and *W. rotundifolia*), is the largest occurrence of this association in Victoria (65 ha) and considered to be of outstanding scientific interest (Yugovic 1985).

The saltmarshes of the Lake Connewarre Complex are recognised as important overwintering habitat for the endangered orange-bellied parrot (Department of Sustainability and Environment 2003). The grey glasswort (*Halosarcia halocnemoides*), a species associated with salt lakes of north-western Victoria, was found for the first time at Murtnagurt Swamp and other locations on the coast of western Port Phillip Bay circa 1984 (Yugovic 1984). According to Yugovic, not only is this species at the southern limit of its range at Murtnagurt Swamp, it provides an important backup food source for the parrot between the seeding periods for beaded glasswort (*Sarcocornia quinqueflora*; June/July) and shrubby glasswort (*Sclerostegia arbuscula*) at a time of the year when there is a general shortage of food (mid-August).

Barson (1976) also noted that stranded sandy ridges were common in the saltmarshes of Barwon Heads, which supported grassland communities dominated by *Stipa teretifolia* (now *Austrostipa stipoides*).

Barson (1976), after Frankenberg (1971), asserted that the amount of land set aside for the conservation of coastal salt marshes was inadequate.

## *7.2* Mangroves

The Barwon River estuary supports the westernmost population of white mangrove (*Avicennia marina* var. *resinifera*) in Victoria (Department of Conservation and Natural Resources 1993). These occur as stunted shrublands along the lower Barwon and its subsidiary tidal creeks, with isolated seedlings and shrubs occurring as far inland as the tidal delta at the exit of Lake Connewarre (Yugovic 1985).

Scientific literature that focuses on Barwon River mangroves is limited to a few research papers and student theses, of which most originate from Deakin University.

Investigations by Gwyther (2000, 2002, 2005), Gwyther & Fairweather (2002, 2004), Bartsch & Gwyther (2004) and Bloink (2001) are primarily focused on the ecology of the meiofauna and epibionts on pneumatophores and in the mud beneath the mangrove canopy. These papers are reviewed in the meiofauna section.

Studies by Billows (1998) on the effects of the physical structure of mangrove habitats on sediment particle size were carried out in the lower Barwon estuary, adjacent to the Ocean Grove golf course. The study showed that median particle size diameter ($MD_{50}$) within areas covered with the white mangrove (*Avicennia marina*) was approximately half of that for adjacent bare mud flats. His investigation showed that the stems and pneumatophores of the mangroves attenuated tidal flow and wave action, thus allowing a greater proportion of fine particles to enter and settle, in contrast to the adjacent non-vegetated mudflats. The importance of mangroves as stabilisers of estuarine mudflats and as a means to "reclaim" land is well established. Coulson (1933) highlighted this point with the statement that "the wide-spreading and quick-growing nature of the mangrove makes it a very effective reclaiming agent".

The effect of particle sorting by estuarine vegetation is likely to have flow-on effects on the distribution of sediment infauna (Billows 1998) and thus foraging preferences for various predatory faunal groups, such as fish and wetland birds. At the same location as Billows' study, Bloink (2001) identified the median particle size of mudflats as a factor for structuring meiofaunal communities.

Davey & Woelkerling (1980) characterised the macroalgal communities on pneumatophores from temperate *Avicennia marina* mangrove ecosystems on the Victorian coast. Of the 23 algal species identified from 16 bays or estuaries, only four were found in the Barwon estuary. They identified three rhodophytes (red algae) (*Bostrichia moritziana, B. radicans* and *Caloglossa leprieurii*) and one chlorophyte (green alga) (*Enteromorpha clathrata*). They concluded that the estuarine communities (including the Barwon) were less diverse than those in the marine embayments such as Crib Point (13 species) and Hastings (eight species) in Westernport Bay. However it is unknown how extensive their sampling was within each site, and how representative their collections are of these macroalgal communities. It may be that further investigation within the Barwon will reveal other species.

Twenty years after Davey & Woelkerling, Lee (2000) investigated the macroalgal community structure associated with mangroves at Barwon Heads and Ocean Grove. Five genera were identified in the study, *Catanella*, *Caloglossa*, *Bostrychia*, *Ulva* and *Enteromorpha*. Two of these are additional to the list compiled by Davey & Woelkerling (1980).

Lee (2000) highlighted the importance of the macroalgal communities as a source of food for herbivorous gastropods and fish. Macroalgae may also assist the diffusion of air at the surface of the pneumatophore by keeping its surface moist (Lee 2000). He also suggested that epibiotic macroalgae within mangroves may be useful as bio-indicators of ecosystem health.

Proposed management actions directly relating to mangroves within the lower Barwon were highlighted in the LCSGR Management Plan and include the prevention of tidal flow interference with, and discouraging human disturbance of, the mangrove flats (Department of Conservation and Natural Resources 1993). The report did not elaborate on what form human disturbance takes or how it would be mitigated.

## *7.3* Seagrass

The Department of Conservation and Natural Resources (1993) identified Lake Connewarre as harbouring extensive meadows of the seagrass *Zostera muelleri*. In contrast, Yugovic (1985) did not observe vascular plant growth within the lake, suggesting that any absence may have been due to fluctuating salinities and wave action. Such a discrepancy suggests that the spatial abundance and distribution of *Zostera* within the lake is highly dynamic and may be greatly affected by fluctuations in water quality (e.g. salinity, nutrients) and/or other environmental conditions, such as siltation rates.

Sherwood (2005) reiterated the observations of an earlier investigation (Sherwood et al. 1988) that isolated colonies of eelgrass (*Zostera* or *Heterozostera* sp.) had existed in the northern arm of the lake and at its exit to the lower Barwon. Photographic evidence by local resident, Ron Scotland, showed a more extensive stand of seagrass approximately 50 m wide, in August 2005, along almost the entire length of the north shore (Sherwood 2005).

Constant remobilization of sediments in the shallows (<0.5 m) of Lake Connewarre may militate against seagrass establishment (Sherwood 2005). However, sedimentation in the northern arm may have improved the conditions for seagrass beds to establish by improving the benthic light climate whilst maintaining a depth where sediment resuspension is kept low. Sherwood also suggested that the expansion of the seagrass beds since 1987 is a reflection of reduced freshwater inflows, associated with over six years of drought, and that an increase in salinity within the lake may have favoured the growth of these plants. It should not be assumed that the extent of seagrass beds within the lake has grown steadily since 1986-7, since it is more likely to have waxed and waned over the past twenty years. Future monitoring of seagrass patch dynamics may provide a better understanding of seagrass responses to lake water quality, in particular, salinity, turbidity and nutrients.

An increase in the distribution of seagrass is likely to improve lake biodiversity, provide a significant food source for grazers, and provide nursery areas for larvae and juveniles of recreationally and commercially important fish species (as well as the non-commercial species) (Sherwood 2005).

The widespread cover of Lake Connewarre's floor with seagrass and seaweed at the time of European settlement (Taylor 1855: PROV, VPRS 44, Unit 470) may be a consequence of the significantly greater depth of the lake then than today. With generally deeper water throughout the lake the degree of resuspension of sediments by wave action may have been significantly less than today, as would sedimentation rates in the northern arm of the lake. Seagrass colonies may have been more stable under these conditions.

Consideration of the above accounts, and those from other locations around Australia and throughout the world, provide evidence of the transient nature of seagrass beds. An opportunity exists to clarify the presence of vascular aquatic plant and macroalgal species within Lake Connewarre, monitor the dynamics of seagrass distribution, and identify the factors specific to Lake Connewarre that affect the transient nature of its seagrass colonies.

## *7.4* Adjacent Terrestrial Vegetation

The terrestrial vegetation surrounding the Lake Connewarre Complex is diverse and represents some significant vegetation communities and species. Yugovic (1985) identified *Melaleuca lanceolata* scrub (moonah woodland) as localised at “The Sheepwash”, Barwon Heads. However, other remnants of this community exist on the eastern fringe of the wetlands near Pacey’s Island, north-east of Campbell’s Point, south-east of Tait’s Point and in the valley which drains into the north-east arm of the lake at Wallington (Billows 2003). Billows also noted that two very large specimens of moonah stand on the southern shores of Hospital Swamp, each with a stem circumference of approximately 4 m (Figure 7-2).

Scattered patches of native grassland and grassy woodland can be found, mainly on the higher northern and eastern slopes of the shores of Lake Connewarre (Billows 2003). These remnants generally consist of the endangered Bellarine yellow gum (*Eucalyptus leucoxylon bellarinensis*), drooping sheoak (*Allocasuarina verticillata*) and lightwood (*Acacia implexa*), with groundcovers of native wallaby grasses (*Austrodanthonia* spp.), kangaroo grass (*Themeda triandra*) and spear grasses (*Austrostipa* spp.), interspersed with wildflowers, such as wattle matt-rush (*Lomandra filiformis*), featherheads (*Ptilotus macrocephalus)*, yellow rush-lilies (*Tricoryne elatior*), and tall bluebells (*Wahlenbergia stricta*) (Billows 2003).

Barwon Water’s *Black Rock Ecosystem Project* aims to enhance environmental outcomes and establish wildlife corridors between the coast and the wetlands of Breamlea and Lake Connewarre (Barwon Water 2006). In the year 2005-2006, 15,000 indigenous plants were planted and areas of native grasslands and wetlands were fenced off for their protection.

*Figure 7-2. Large old Moonah on the shore of Hospital Swamp.*

*Figure 7-3. Vegetation on Lake Connewarre north east of Campbell's Point.*

## *7.5* Weeds

### *7.5.1* Spartina *(Cordgrass)*

*Spartina* is an erect, halophytic rhizomatous grass that grows in estuarine environments throughout much of the world (Bailey 1995). It has the ability to accrete large amounts of sediment and was introduced to Australia in the 1930s as a means of land reclamation (Dedman 1994; Bailey 1995; Boekel 1995). Due to its invasive nature, *Spartina* also has the ability to rapidly colonise mudflats and displace seagrass and saltmarsh vegetation.

In 1930-1931, the Geelong Harbour Trust introduced 3000 *Spartina* plants into the lower Barwon River estuary and the northern and southern shores of Lake Connewarre (Bailey 1995; Boekel 1995). This was done in a bid to reclaim "much of the shallow lake bed" for grazing. In February 1994, members of the Geelong Field Naturalists Club noticed the emergence of *Spartina* on the mudflats of the Barwon estuary (Boekel 1995). *S. anglica* and *S. x townsendii* were identified by the Melbourne Herbarium. Mapping of the *Spartina* outbreaks was carried out throughout the upper and lower reaches of the Barwon estuary. A map of the estuary shows the areas planted in 1930-31 and the known sites that were treated in 1994-95 (Boekel 1995). Between 80 and 100 clumps were found in 1994-95. Each clump was marked with a numbered plastic tag attached to a length of wire which was driven into the mud. The markers provided the dates of when the clumps were found and treated. Three treatment options were investigated, including spray applications of herbicide, covering with black plastic and hand pulling. None of the control methods was deemed to be viable due to the difficulties associated with tidal currents and inundation, the soft muddy substrate and the extensive root system of *Spartina*.

The *Spartina* clumps were sprayed with Fusilade, diluted 100:1, mixed with a wetting agent (Agril) and a red non-toxic dye. The treatments took place at low tide in late November 1994, and again in late February 1995. A rain event soon after the first treatment may have affected the herbicide performance. Interim results of the trial indicated that *Spartina* was showing signs of stress (loss of rigidity and paling of colour). Annual treatments were planned for the following two years. No adverse affects of the Fusilade were observed on beaded glasswort and mangrove seedlings two months after the applications.

In the summer of 1994-95, Bailey (1995) reviewed the literature relating to the biology and ecology of *Spartina* and undertook a study of its distribution within the lower Barwon estuary, including the tidal delta at the exit of Lake Connewarre. Management recommendations were made based on the biology and ecology of the species and of available control measures. A twelve-point management guide was proposed.

Bailey identified and mapped five areas of *Spartina* infestation located along the following sections of the Barwon estuary:

1. A group of isolated plants and clones on mudflats and seagrass beds, south (downstream) of the Ocean Grove boat ramp.
2. Two large, dense swards, with some clumps and clones lining a drain upstream of the boat ramp and invading adjacent mangrove and samphire communities. This was the largest infestation (64 $m^2$).
3. Clumps with dense growth on the south side of the river at The Sheepwash.
4. A sward with open growth clones and clumps growing within the pneumatophore zone of mangroves, within a creek on the northern side of the river, opposite the Sheepwash.
5. Two clumps within the tidal delta of Lake Connewarre adjacent to saltmarsh vegetation.

These locations correspond with the map presented by Boekel (1995).

*Spartina anglica* was the only species identified during the study. It was observed growing in grey silty clay or a mixture of grey silty clay and fine sands. *Spartina* was also found to be flowering within all sections surveyed in Bailey's study.

Bailey recommended further research into the development of better control methods for *Spartina*, including biological control. He also proposed research into watershed management, as growth rates in *Spartina* have been linked to increased sedimentation rates (Bailey 1995, after Franko et al. 1985).

### *7.5.2 Tall Wheat Grass*

Tall wheat grass (*Thinopyrum elongatum*) is an environmental weed that tolerates saline conditions (Department of Sustainability and Environment 2003) and is considered a potential threat to naturally saline wetlands, as discussed in the Port Phillip Bay (Western Shoreline) and Bellarine Peninsula Ramsar Site Strategic Management Plan. However, the plan does not refer to any outbreaks of this species within the wetland system, except for the threat of an outbreak from a source on Hovells Creek, which enters Limeburners Bay north of Geelong. Billows (2003) identified several tall wheat grass infestations on the shores of Lake Connewarre and Hospital Swamp during his assessment of wetlands in January 2003. Harding (2002) has also recorded some of these outbreaks in a wetland database. A likely source of seed is from an area of upper saltmarsh on the eastern shoreline which was previously sown with this salt-tolerant pasture species. Seed dispersal around the lake system may be due to transfer by a combination of floodwaters and lake currents during spring tides.

### *7.5.3 Other weeds*

Many other weed species occur within the Lake Connewarre Complex, and may threaten the integrity and viability of the native floral communities (Department of Conservation and Natural Resources 1993). Species of particular concern include annual beardgrass (*Polypogon monspeliensis*), sea barley grass (*Critesion marinum*) and small saltbush (*Atriplex prostrate*). A number of noxious weeds also exist, including boneseed (*Chrysanthemoides monilifera*), spear thistle (*Cirsium vulgare*) and horehound (*Marrubium vulgare)*. Introduced species are listed in Appendix B and tagged with an asterisk.

## *7.6* Summary and issues

- The flora of the Lake Connewarre Complex is significant in terms of its extent, condition and floristic diversity.
- Early information on the flora of the Lake Connewarre Complex is very limited.
- Yugovic's (1985) comprehensive characterisation and analysis of the floristic and structural composition of the Lake Connewarre Complex provides a strong basis for the understanding and management of the wetland flora of the system.
- Very few reports exist on the ecology of the flora of the Lake Connewarre Complex and its exposure and responses to human impacts (e.g. pollution, nutrient enrichment, weed invasion and the threat of rising sea levels associated with global warming).
- *Spartina* and tall wheat grass are two introduced species that have invaded the wetlands and have the potential to displace large areas of native saltmarsh. *Spartina* outbreaks have been traced, recorded and actively managed. However, there are no records of attempts to assess the severity and manage outbreaks of tall wheat grass infestations.
- Local studies of mangrove ecology have been undertaken within the Lake Connewarre Complex, most of them by Deakin University. Opportunities exist to understand the ecology of other wetland habitats within the system (e.g. freshwater marshes, saltmarshes and seagrasses). A focus on ecological responses to human-derived issues such as reduced environmental flows, rising sea levels, pollution from stormwater, nutrient enrichment and the invasion by introduced terrestrial and marine pest species and their management should be developed.
- Opportunities exist to test the use of indicator flora as an early warning to the onset of ecosystem disturbance and decline associated with pollution, climate change, altered flows, salinity changes and other impacts.

# 8 Fauna

> *The lower Barwon River, Lake Connewarre, and the associated flood plain have an estuarine fauna not found elsewhere along the Victorian coast. It includes species specially adapted to fluctuations in salinity, from full salt water to full freshwater conditions, over both short and long periods.*
>
> *(Land Conservation Council 1973)*

On the basis of this statement, supporting data, and considering submissions from various organisations and individuals, the Land Conservation Council Victoria (1977) recommended that the wetlands of the Lake Connewarre Complex:

> *… be used primarily to conserve native animals, and for public education and recreation where this does not conflict with the primary aim; and that particular care be taken to protect the sites of special conservation significance on the coast that are within this reserve; and that it be permanently reserved under section 14 of the Land Act 1958, and managed by the Fisheries and Wildlife Division.*
>
> *(Land Conservation Council 1977)*

Surprisingly few written accounts of the fauna, other than birds, associated with the Lake Connewarre Complex exist, especially considering the importance of this area as habitat for what is proclaimed as a unique assortment of species.

The Corangamite Wetland Inventory Database (Harding 2002) provides lists of vertebrate species and an estimate of the number of invertebrates encountered during 25 wetland site assessments of the Lake Connewarre Complex in 2002. However, it gives no specific details about the types of invertebrates found.

Since 1997, members of the Geelong Field Naturalists Club have been monitoring several of the biotic components of Reedy Lake. The “Reedy Lake Study” was initiated to monitor the “recovery” of the lake ecosystem after the lake was drained in a bid to exterminate carp (*Ciprinus carpio*), which were destroying the lake vegetation (Pescott 1998). The study focused on surveys of birds, frogs and aquatic invertebrates, and changes in water levels and vegetation. Regular findings of the study were presented to the Reedy Lake Management Group to aid the appropriate management of the lake to “maintain ecological diversity” (Pescott 1998).

A recent search of the Atlas of Victorian Wildlife (AVW) Database (Department of Sustainability and Environment 2007a) for the Lake Connewarre Complex revealed:

- ten mammal species (three introduced)
- 199 bird species (11 introduced, 47 listed under Victorian Rare or Threatened Species (VROTs), 20 listed as threatened under Schedule 2 of the *Flora and Fauna Guarantee Act 1988* (FFG Act), one listed as endangered and two listed as vulnerable under the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act)
- two reptile species (both native, one snake and one skink)
- three frog species (all native, one species listed as threatened under the FFG Act, vulnerable under the EPBC Act and endangered under VROTs)
- 20 fish species (five introduced, one species listed as threatened under the FFG Act, vulnerable under the EPBC Act and vulnerable under VROTs)
- two invertebrate species (one butterfly and one freshwater shrimp).

A list of these species is presented in Appendix C. Using the AVW list as a base, an opportunity exists to update this list or establish a separate comprehensive faunal (and floral) list for the Lake

Connewarre Complex by combining all other available records of species sourced from the references within this review and other sources. This would provide a more accurate representation of the fauna and flora of the study area. Efforts should be made to establish the accuracy and legitimacy of the referenced floral and faunal data that are added to the list.

## *8.1* Birds

The Lake Connewarre Wildlife Reserve is listed as a wetland of national (ANCA 1996) and international importance. The reserve forms part of the Port Phillip Bay (Western Shoreline) and Bellarine Peninsula wetlands system, listed under the *Convention on Wetlands* (Ramsar Convention Secretariat 2006). The significance of the reserve has been emphasised mainly for its capacity to support a diverse range of avifauna (Australian Nature Conservation Agency 1996).

The Land Conservation Council Victoria (1973) identified the lower Barwon and associated wetlands as a very important link in the chain of wetlands along the east-west flyway for migratory waterfowl. The area provides feeding and breeding grounds for a range of waterbirds, including large numbers of migratory waders and waterfowl, and resident species (Department of Conservation and Natural Resources 1993). The wetlands are also an over-wintering site for the endangered orange-bellied parrot, *Neophema chrysogaster* (Department of Conservation and Natural Resources 1993).

Up to 1993, 149 avian species had been recorded in the Lake Connewarre State Game Reserve, which has regularly supported over 10,000 ducks and swans (Department of Conservation and Natural Resources 1993). At the time of publication, the management plan for the reserve had five bird species listed as threatened under Schedule 2 of the Flora and Fauna Guarantee Act (1988), 20 species listed under the Japan–Australia Migratory Birds Agreement (JAMBA) and 25 species listed under the China–Australia Migratory Birds Agreement (CAMBA). Current records from the AVW Database (Department of Sustainability and Environment 2007a) add another 50 bird species to the 1993 list. The number of species listed as threatened under the FFG Act 1988 has increased to 20 (Appendix C).

Many of the avifaunal records have originated from observations made by bird observers and field naturalists, either individually or as organised groups. Very few accounts of bird surveys have been published. Occasional articles have appeared in organs such as the *Victorian Naturalist* and the *Geelong Naturalist*. Members of the Geelong Field Naturalists Club have been particularly active in recording birds within the Geelong region and on many occasions within the Lake Connewarre Complex. These records are scattered through the many issues of the *Geelong Naturalist*, dating back to 1881, when the club was founded. Many records from the wetlands are combined with observations from other areas of Geelong. However, several articles from this journal focus on the Lake Connewarre Complex or at least provide a substantial account of the wetlands within their featured article. Some provide species lists only, whilst others incorporate more or less detailed observations of habitat characteristics, bird numbers and feeding, nesting and other behavioural activities.

An early article by Shaw (1893) provided probably the first recognition of bird migration within the Lake Connewarre Complex. Knowing little of the birds that inhabited the wetlands, he speculated about the propensity of several species to migrate. Soon after, Mulder (1896) concluded that the molluscs *Bulinus* sp., *Potamopyrgus nigra* and *Pisidium etheridgei* within Lake Connewarre were the principle source of food for the large flocks of black swans and coots that inhabited the lake. This was based on his repeated observations of the shells of these species within the gizzards of dissected birds.

Other pertinent articles followed (e.g. Mulder 1898, Smith 1969, Abbott & Hughes 1972, Minton 1980, Pescott 1981, Bottomly 2004). The Geelong Field Naturalists' Bird Study Group produces an annual Geelong Bird Report, first published in 1986 in the *Geelong Naturalist* (1986-1992), before becoming an independent publication from 1993 to the present. While this publication records bird sightings from throughout the Geelong region, records specifically from the Lake Connewarre

Complex are regularly reported (e.g. Russell 1986, Russell 1987, Pescott 1989, Hewish 1993, Hewish 1993).

In 1970 Pescott, compiled a list of 84 bird species from Lake Murtnagurt, a shallow saltwater lagoon behind the sand dunes at Thirteenth Beach. Although the vegetation surrounding Lake Murtnagurt is considered suitable habitat for the orange-bellied parrot (OBP) (Yugovic 1984) and is a designated location for OBP winter surveys, Pescott's 1970 list and recent survey records do not identify this endangered species there.

Mackenzie et al. (2005) provide a detailed account of the bird records of Reedy Lake in the *Geelong Bird Report 2005*. The report presents the findings of many years of surveys and observations, dating back to Belcher's records of 1914 and including the Reedy Lake Study of 1997-2000. Significant information from the report includes:

- 148 bird species listed since Charles Belcher's observations
- A summary of results of summer and winter counts of waders from 1981 by the Royal Australian Ornithologists Union (RAOU) and the Australian Wader Study Group (AWSG), including number of species and total numbers of birds, plus a summary of waterfowl counts by the Department of Natural Resources and Environment and RAOU from 1987 to 1992
- 15 species observed to have had 1000 or more individuals present on at least one occasion
- A list of 53 bird species with special conservation status and/or significant populations (including the internationally significant orange-bellied parrot, *Neophema chrysogaster*)
- Reedy Lake regarded as an important link for the passage of birds [e.g. brolga (*Grus rubicundus*), lesser yellowlegs (*Totanus flaripes*) and others] between local wetlands such as the lower Barwon wetland system and the Moolap saltworks
- Breeding colonies of ibis and spoonbills within Reedy Lake often exceeding ten thousand nests.

It is Reedy Lake's extensive reed beds that provide suitable colonial nesting locations for several wetland bird species, in particular colonies of straw-necked and sacred ibis (Corrick 1982).

Gray (1934) contributed a brief account of bird life on the lakes as an addition to Coulson's (1933). Gray recognised the Connewarre wetlands as a "paradise" for waterfowl and waders, remarking that "few other similar areas offer such a variety of swamp-loving birds". The exploitation of the lakes by professional and recreational shooters over the previous 50 years had, according to Gray, depleted the flocks of ducks and other waterbirds. The disappearance of the Cape Barren goose from this area and the rest of the mainland is a likely result of early hunting activity. Sharp-tailed (sandpipers) and little stints were also targeted by hunters and sold in markets at threepence a pair. These birds often flocked in their thousands. Gray recorded several other birds, often together with some characteristic physical feature, behaviour or detail of their habitat. With only common names being used it is sometimes unclear which species are being referred to (e.g. brown bittern, a name not used in modern field guides).

Pescott's account of birds in the Geelong region (Pescott 1983) regularly mentioned Lake Connewarre, Reedy Lake and Hospital Swamp as sites of local bird records. He summarised his observations and those of others back to Belcher (1914). Each known bird species within the area received a brief history and, where applicable, an expansion or decline in population is recorded. Pescott also includes a "Location Chart", which summarises where each species had been sighted up to 1983. Records for the two locations, Connewarre and Moolap, are likely to approximate those for the Lake Connewarre Complex.

The importance of these wetlands as a destination for many migratory waders has prompted the Victorian Wader Study Group and AWSG to conduct regular surveys within the Lake Connewarre Complex. The AWSG has carried out a total of 224 wader surveys at five locations between 1983 and 2004 (Australian Wader Study Group, undated). The five sites are Lake Connewarre (49 surveys), Reedy Lake (44 surveys), Hospital Lake (Swamp) (45 surveys), Lake Murtnagurt (44 surveys) and the Barwon Estuary/River (42 surveys).

Over 160,000 waders and 33 species have been recorded by the AWSG over the 21-year period. The greatest abundances have been recorded on Lake Connewarre (76023 waders) and Hospital Swamp (54464 waders).

| | All Sites | Lake Connewarre | Reedy Lake | Hospital Lake | Lake Murtnagurt | Barwon Estuary & River |
|---|---|---|---|---|---|---|
| No. of Surveys | 224 | 49 | 44 | 45 | 44 | 42 |
| No. of Waders Recorded | 160542 | 76023 | 20359 | 54464 | 5263 | 4433 |
| No. of Species Recorded | 33 | 25 | 14 | 17 | 15 | 21 |

*Table 8-1. Surveys of Wading birds in the Lake Connewarre Complex.*

Many of the migratory waders are from the northern hemisphere, from where they migrate annually to the Lake Connewarre complex for the southern spring and summer, along with shorebird species such as the whiskered tern. Ducks and other waterbirds concentrate in these areas for the summer and often use them as a drought refuge (Mackenzie et al. 2005).

The factors that control the number of species of wetland birds in an area at any one time are complex. The movement of migratory species depends on more than the availability of wetland types, but also on nationwide rainfall patterns and the length of the day (Corrick 1982). The distribution of wetland avifauna can be closely linked to the distribution of potential food sources, especially where elevated salinities are present (Corrick 1982). This may help explain why the wetlands of the Lake Connewarre Complex, with their various and fluctuating salinity regimes, attract such a great diversity of birds.

## *8.2* Fish

The LCSGR provides important habitat for over twenty species of native fish (Department of Conservation and Natural Resources 1993, after Land Conservation Council Victoria 1983). The LCSGR Management Plan (Department of Conservation and Natural Resources 1993) primarily summarised the findings of Tunbridge (1988) to characterise the fish communities, the habitats that support the communities, and the nature of existing and potential threats to the communities.

In *Water Victoria: An Environmental Handbook* (Department of Water Resources Victoria 1989), available information on the distribution of fish species within Victorian basins was compiled and presented on basin maps. For the Barwon Basin, 14 fish species were listed from Lake Connewarre (six native migratory, four native non-migratory and four introduced species), whilst four species were listed for the lower Barwon estuary near Ocean Grove (four native migratory and one native non-migratory). There were no records for other locations within the Lake Connewarre Complex, including Reedy Lake or Hospital Swamp. However records from above the lower breakwater were published. The major source of data for this report was the Fisheries and Wildlife Division of the Department of Conservation, Forests and Lands, whilst other sources included published papers, unpublished reports and academic theses. Lists of the fish assemblages for each site were not necessarily complete for a range of reasons. For instance, some investigations may have recorded targeted species only (e.g. commercial or recreational fish species).

Tunbridge and Glenane (1982) rated the value of waters within the Connewarre Wetlands Complex in terms of their recreational or commercial fishing amenity or their fish conservation amenity. The waters rated were the lower estuary of the Barwon River and Lake Connewarre. Reedy Lake was not surveyed and therefore not assessed. The lower Barwon River estuary was considered a valuable resource in terms of sport fishing, especially for black bream (*Acanthopagrus butcheri*) and mulloway (*Argyrosomus* sp.) whose fisheries value for these waters was rated as average (Tunbridge & Glenane 1982, after McCarraher 1976). The estuary was considered to be of high commercial value for the short-finned eel (*Anguilla australis*) fishery (Tunbridge & Glenane 1982, after McCarraher 1979). Nine other species were identified as contributing to the commercial and recreational fisheries value of the Barwon estuary.

Tunbridge & Glenane (1982) also rated Lake Connewarre as having high conservation value for estuarine species, with 17 native fish species identified. Four introduced species, brown trout (*Salmo trutta*), European carp (*Cyprinus carpio*), tench (*Tinca tinca*) and redfin (*Perca fluviatilis*), were also recorded in the lake.

One of the most comprehensive fish surveys in the Lake Connewarre Complex was carried out by the Department of Conservation Forests and Lands between April 1986 and June 1987 as part of a Water Management Strategy Task Force for the south-west region of Victoria (Tunbridge 1988). In his recommendations of suitable environmental flows for the maintenance of fish populations in south-west Victorian rivers, Tunbridge (1988) recorded 17 fish species captured by gill or fyke nets. At least another four smaller fish species were caught.

Within Lake Connewarre, yellow-eye mullet (*Aldrichetta forsteri*), short-finned eel and black bream were the most abundant species captured in gill and fyke nets during the survey period. Of the small fish, common galaxias (*Galaxias maculates*), small-mouthed hardyhead (*Atherinosoma microstoma*) and flat-headed gudgeon (*Phylipnodon grandiceps*) were most abundant. Tunbridge observed that black bream concentrated near the exit of the lake during conditions of low salinity (fresh water), but congregated west of Tait’s Point during periods of high salinity. Yellow-eye mullet were found to be more evenly dispersed throughout the lake.

Large numbers of common galaxias and broad-finned galaxias larvae were found in the lake and lower Barwon during freshwater conditions between June and August 1987. Juvenile fish of these species, Australian smelt (*Retropinna semoni*) and brown elvers of short-finned eels were observed migrating upstream, past the lower barrage.

The suite of estuarine species in Lake Connewarre was considered to be similar to those of other Victorian estuaries.

Tunbridge (1988) concluded that the Barwon River, from below the lower breakwater to Lake Connewarre, was of “average” fisheries value, largely based on angling for black bream and commercial fishing for short-finned eel. Lake Connewarre, on the other hand, was designated “high” fisheries value, based on its importance as a spawning and nursery area for tupong (*Pseudaphritis urvillii*), broad-finned galaxias (*Galaxias brevipinnis*) and common galaxias (*Galaxias maculates*). Tunbridge also suggested that the lake may be important for the early development of Australian grayling (*Prototroctes maraena*) larvae. Flow recommendations for Lake Connewarre include:

- That the observed annual cycle of saline to freshwater conditions within the lake be maintained
- That sufficient river flow of freshwater (3000-5000 Ml day$^{-1}$) should occur in June or July to coincide with natural flooding and spawning of grayling, and that freshwater or low-salinity conditions within the lake be maintained for at least two months
- That during low river flows between January and April, salinities should not exceed 28 parts per thousand (ppt) and during high flow should be less than 20 ppt
- The installation of a fish passage at the lower barrage to assist the movement of fish, especially the upstream migration of juveniles.

In the Reedy Lake survey, Tunbridge (1988) reported the capture of eight species of fish using gill and fyke nets from one sampling event in May 1986. English perch (redfin; *Perca fluviatilis*) and short-finned eels were the most abundant. Tunbridge's assessment of the lake's angling and conservation value was "low". He also suggested that there be no requirement for a "freshwater allocation for fish in Reedy Lake", but the maintenance of freshwater conditions for wetland bird habitat may be necessary.

Hall & Tunbridge (1988) documented the findings of another survey which was part of the greater investigation of the Barwon River system and prompted work by Tunbridge (1988), Sherwood et al. (1988) and others to address the ecological effects of reduced flows in the river. Sampling at the lower barrage near Reedy Lake led to the capture and identification of eleven fish species (seven native and four introduced). Their study provided details of the distribution of several of the smaller forage fish species that inhabit the river. Five specimens of the nationally threatened Australian grayling were caught at the barrage.

McCarraher & McKenzie (1986) identified the Barwon River and Lake Connewarre amongst 57 Victorian rivers and lakes that supported populations of estuary perch (*Macquaria colonorum*), based on a six-year netting survey between 1975 and 1989. The Barwon River ranked third of all surveyed drainages in supporting significant populations of estuary perch, according to the mean length of perch sampled (41.2 cm). Mallacoota Inlet ranked first with a mean length of 42.4 cm and the Nicholson River last with a mean length of 21.1 cm. Lake Connewarre was not included in this ranking. Although McCarraher & McKenzie (1986) did not elaborate further on the Barwon River and Lake Connewarre populations, they established that estuary perch grew fastest and lived longest in deep-channelled rivers (such as the Barwon). A greater knowledge of the life histories of fishes within the Lake Connewarre Complex would be useful in better managing these populations.

A study by Myers (1988) examined the nature and extent of recreational use of the Barwon River and its fish resources and found that the Barwon River was an important angling resource. Angling accounted for 12% of the overall participation in recreational pursuits behind passive recreation, e.g. picnicking, sunbaking and sightseeing (55 %), and rowing/canoeing (14 %). Downstream of the barrage, the mean catch rate was calculated at 0.56 fish per hour. Yellow-eye mullet and black bream were the most commonly caught species, whilst silver trevally (*Pseudocaranx dentex*) and short-finned eels were caught by anglers in much smaller numbers.

The utilisation of mangrove habitat by small and juvenile fish at Barwon Heads and Ocean Grove was investigated by Baumgartner (1998). A total of 2282 individuals, representing 14 species, were caught in seine nets over a four-month period from mid-April to the end of July. The hardyhead (*Leptatherina presbyteroides*) comprised 80% of the catch, with yellow-eye mullet and Tamar River goby (*Favonigobius tamarensis*) making up 12% and 4% of the total catch respectively. Fish of commercial importance were found to be poorly represented. These included King George whiting (*Sillaginoides punctata*), black bream and greenback flounder (*Rhombosolea tapirina*).

Factors affecting fish abundance included the lunar phase, diel phase, mangrove density and food resource availability. Baumgartner (1998) concluded that lunar phase did not affect fish abundance in mangroves. Tamar River goby and garfish (*Hyporhampis melanochir*) were found to exhibit higher numbers nocturnally, whereas common galaxias were more abundant diurnally. Tamar River goby was the only species to be affected by mangrove density (i.e. more abundant at low mangrove density).

Baumgartner (1998) also investigated the effects of oral morphology (mouth size) of fish on foregut contents and the partitioning of food resources within the mangrove habitat. Calanoid and harpacticoid copepods contributed to 52% (by number) of the gut contents (26% each), whilst amphipods contributed 16%. Thirteen other groups of prey items were found less frequently. He reported that the diet of fish differed significantly with oral size for each of the three most abundant fish. When foregut contents were correlated with sediment fauna, only one fish species, the hardyhead, exhibited a significant correlation (Spearman correlation coefficient = 0.493, $p<0.05$).

This led Baumgartner to argue that small and juvenile fish may use mangrove habitat within the Barwon River for the avoidance of predators as well as foraging, especially at night.

Sherwood et al. (1988) reported nine fish species as by-catch from their macroinvertebrate surveys. Eight species were recorded from Lake Connewarre, two from Reedy Lake and two from the Barwon estuary below Lake Connewarre. Fish were found to be in greatest abundance where aquatic vegetation was present. These locations included the eastern bay of the north-east arm of Lake Connewarre, where seagrass dominated (species not identified), and the entrance to Lake Connewarre, where the common reed (*Phragmites australis*) occurs.

Thirty-two native fish species and seven exotic species were identified as inhabiting the estuary complex by EFTP (2005a). These fish contributed to a larger list for nine reaches within the Barwon River catchment, compiled from previous reports by Tunbridge (1988), DCNR (1995), Zampatti & Grgat (2000), Raadik (2000), DNRE (2001) and Zampatti & Koster (2002). This information was used as a means to characterise the environmental values and condition of the river system from its headwaters and tributaries to its mouth at Barwon Heads. The presence and predatory behaviour of some of the exotic species is having a significant effect on native fish populations (CCMA 2005, after Zaret 1980, Fletcher 1986, Lloyd 1987).

Fabris & Theodoropoulos (1999) reported that mercury concentrations in short-finned eels sampled from the lower Barwon River (0.32 µg $g^{-1}$) were comparatively higher than those collected from 18 other rivers and lakes (0.01–0.21 µg $g^{-1}$) in southern Victoria during the same study. Elevated mercury levels in eels in the lower Barwon may reflect past gold mining activities in the catchment, though the drainage of stormwater from industrial and urban sectors of Geelong may also contribute. The same study detected residues of DDT compounds in eels, with the highest concentrations again found in eels from the lower Barwon River (104 ng $g^{-1}$). As with mercury, Fabris & Theodoropoulos (1999) suggested that the developed Barwon catchment and stormwater runoff from Geelong may explain the higher DDT residues in eels from the lower Barwon.

Although exact locations of the sampling sites were not provided, it is possible that similar levels of mercury and DDT residues would be found in eels and other teleosts that inhabit various sites within the Lake Connewarre Complex, given the wetlands' ability to trap sediments, nutrients and contaminants transported from the upper catchment. Non-migratory fish, or those species which spend a considerable period of their life cycle within the wetland system, are most likely to accumulate these and other contaminants within their tissue. Biomagnification is also a major ecological process causing these contaminants to accumulate in eels, as the main prey for eels are insects and other teleosts. In this situation, contaminants are concentrated in species at higher trophic levels.

None of the mercury or organochlorine and organophoshate residue levels were above the ANZA Food Standards Code, indicating that no human health issues would be associated with these contaminants in eels within the sites studied (Fabris & Theodoropoulos 1999). The authors recommended the continued monitoring of the lower Barwon River for mercury to determine if concentrations increase with time and to measure the contribution from urban and industrial runoff. They also suggested that assessments of organophosphate residues be undertaken at five-year intervals, and that future assessments also target synthetic pyrethroid insecticides as they replace organophoshate-based insecticides.

## *8.3* Mammals

In 1993 the Lake Connewarre State Game Reserve Management Plan listed 14 mammalian species that had previously been recorded in or adjacent to the reserve (Department of Conservation and Natural Resources 1993, after the AVW). The eastern barred bandicoot (*Perameles gunnii*) is presumed locally extinct as the last record was in 1881. The water rat (*Hydromys chrysogaster*) was considered common in Reedy Lake and the Barwon River (Department of Conservation and Natural Resources 1993, after Tim O'Brien, personal communication). Coulson (1935) highlighted the predation of eggs and young of black swans by water rats from their nests on Reedy Lake. Current records sourced from the AVW list only 10 species (Appendix C).

## *8.4* Reptiles

There are few published articles referring to accounts of reptiles within the Lake Connewarre Complex. The LCSGR Management Plan (Department of Conservation and Natural Resources 1993) listed 12 reptile species previously recorded in the reserve. The reptiles consisted of seven species of skink, two species of snake, one dragon, one tortoise and one gecko species. Several of these reptiles were not listed on a recent search of the AVW Database (Department of Sustainability and Environment 2007a).

## *8.5* Frogs

There are few published articles referring to frogs within the Lake Connewarre Complex. The LCSGR Management Plan (Department of Conservation and Natural Resources 1993) listed five frog species recorded in the reserve. The report suggests that six other frog species may also be present. The Geelong Field Naturalists Club has identified at least four species from Reedy Lake (Pescott 1998, 2000).

## *8.6* Invertebrates

### *8.6.1* *Macroinvertebrates*

The most comprehensive study of macroinvertebrates within the Lake Connewarre Complex was undertaken by Sherwood et al. (1988) between March 1986 and March 1987. More than 138 taxa were recorded from seven sampling sites. Three sites were within Lake Connewarre (including the lake entrance), two sites in the estuary below the lake, one site in Reedy Lake and one site approximately 6 km above the lower breakwater. Overall community composition consisted of 22% molluscs, 18% crustaceans, 9% polychaetes, and 34% insects. In terms of macroinvertebrate species richness, the Barwon estuary complex (113 taxa, not including those from Reedy Lake or above the breakwater) was considered to be "intermediate" compared to other Australian estuaries.

Sherwood et al. (1988) also observed that the macroinvertebrate composition differed from other Australian estuaries, in that although the proportion of gastropods was similar, the diversity or abundance of bivalve molluscs, crustaceans and polychaetes were proportionally lower. The amphipod fauna was quite diverse, with 13 species recorded. Species richness declined from the lower estuary to Lake Connewarre, but increased in the upper Barwon estuary and Reedy Lake. Sherwood et al. (1988) regarded this pattern as confirmation of Sanders's (1968, cited in Wolff 1983) theory that lowered diversity results from environmental instability or unpredictability. They also proposed that Lake Connewarre contradicts the expectation that high species diversity is associated with Australian seagrass habitats. The macroinvertebrate community within Reedy Lake was considered characteristic of a typical freshwater lentic system, suggesting that Reedy Lake experiences very little influence from the neighbouring estuarine environment.

Sherwood et al. (1988) concluded that if salinity within Lake Connewarre approached that of seawater, a true estuarine fauna may be displaced by one from the lower estuary. "Species richness of the estuarine lake fauna could be seriously affected". They suggested that salinities exceeding 55-60% during low flow may greatly reduce species richness within the lake, and recommended increased control of lake salinity in order to maintain macrofaunal populations.

### *8.6.2* *Zooplankton*

A comprehensive investigation of zooplankton communities was carried out within Lake Connewarre, Reedy Lake and the lower estuary as part of the major study described above (Sherwood et al. 1988). The information in this section is drawn from that comprehensive study. At least 42 taxa were collected and identified from seven sites, of which 25 species are holoplanktonic (i.e. exist as plankton throughout their entire life cycle) and the remaining taxa are meroplanktonic (i.e. exist as plankton for part of their life cycle). Coelenterata, Rotifera, Annelida, Mollusca, Crustacea and Chordata were represented in the plankton.

Species richness was highest in Reedy Lake and the estuary downstream of Lake Connewarre, but was lower within Lake Connewarre. However, graphical representation of the data suggests that there may not be significant differences in mean species richness between these three water bodies. Zooplankton density was highest in Reedy Lake, with rotifers and cyclopoid copepods being the dominant forms, and in Lake Connewarre, where the copepod *Gladioferens pectinatus* was dominant. The lower number of species found in Lake Connewarre may be due to the lake's physiologically extreme environment (Sherwood et al. 1988).

Zooplankton species were grouped into guilds based on their propensity to live in certain salinity regimes. Group 1 was classified as "euryhaline-marine" and was characteristic of the lower Barwon. Group 2 is the "true estuarine" fauna and was characteristic of Lake Connewarre with occasional records in the lower estuary. Group 3 consists of the "freshwater/estuarine" fauna and were more likely to be found in Reedy Lake and the upper Barwon (above the lower breakwater).

Sherwood et al. (1988) observed seasonal fluctuations in zooplankton communities, with the copepods *Gladioferens* and *Sulcanus* appearing to exhibit periods of seasonally high abundances, when peak densities tended to coincide with, or closely follow, peak river discharges. They suggested that zooplankton may be dependent for food on the inputs of particulate organic matter from upstream, as the phytoplankton community within the estuary complex is impoverished. The paucity of the meroplankton community indicated that macroinvertebrates and fish within the Barwon estuary complex may not be as well established as those in other Victorian estuaries.

Sherwood et al. (1988) provided scenarios for the effects of reduced discharge and increased salinity on zooplankton within the lakes and estuary. If salinities were to approach that of seawater, then euryhaline or marine species might begin to dominate zooplankton communities within Lake Connewarre. Reduced river discharges might negatively affect zooplankton production, due to a reduction in the supply of allochthonous material, upon which the zooplankton within Lake Connewarre is dependent. Zooplankton would be adversely affected by an increase in salinity that exceeded five parts per thousand.

### 8.6.3 *Meiofauna*

The inclusion of the meiofauna in ecological surveys is a relatively recent addition to the benthic inventory of aquatic systems. These microscopic animals live within the sediment and on the surfaces of submerged or intertidal macrophytes (plants and algae). Their high abundance and diversity, rapid life cycles, lack of a pelagic larval stage, and intimate contact with the sediment provide good reasons to utilise the meiofauna as environmental indicators of the benthos. The meiofauna are consumers of bacteria and microalgae and are of value as a source of food for both the infauna and browsing demersal fish. Their ecological role in estuaries was reviewed by Coull (1999).

Studies of meiofauna in the Barwon estuary were made initially in the intertidal area adjacent to the mangroves (*Avicennia marina*) near the river mouth at the Guthridge Street boat ramp. Gwyther (2000) reported distinctive and discrete assemblages dominated by nematodes, copepods and ostracods living upon the surfaces of emergent mangrove roots (pneumatophores) as well as in the sediment. The phytal meiofauna assemblages were characterised depending on whether the mangrove roots were fouled by barnacles or by algae. Even leaf litter on the mangrove floor was shown to support particular meiofaunal assemblages (Gwyther 2003). The average density of meiofauna was found to be generally 2000 animals per 10 square centimetres of sediment surface (2 million per square metre), and is numerically dominated by nematodes. Approximately 100 species of nematode worms have been collected and identified from the estuary, including Lake Connewarre.

Subsequent meiofaunal projects in the Barwon included manipulative experiments to investigate colonisation and dispersal (Gwyther & Fairweather 2002), recruitment (Gwyther & Fairweather 2005) and grazing (Gwyther 2005). In 2001 an honours study examined the effects of stormwater discharges on meiofauna of the estuarine mudflats. In this project, Bloink (2001) found disturbance effects from discharges were detectable up to 50 m from stormwater pipes on the shore.

Studies on this ubiquitous faunal group have recently been extended to develop a model of biodiversity gradients within the estuary (Byrne 2004, Gwyther in preparation). The latter project reveals a linear trend between the variation of salinity and the species richness of meiofauna.

The first Australian record of a species of marine mite known previously only from the northern hemisphere was recently recorded from the Barwon estuary mangroves (Bartsch & Gwyther 2004). The mite, *Isobactrus uniscutatus*, is likely to have come from northern Europe and might have been transported to Australia with hard ballast a century ago. This finding is of particular interest because meiofauna are not included in surveys of non-indigenous fauna, but may comprise a significant addition to the currently estimated 10% of Victorian marine species considered to be of exotic origin.

Current trends in aquatic monitoring favour the use of meiofauna in habitats where macrofauna are scarce or where sampling adequate volumes of sediment is costly. The relatively low diversity and abundance of macrofaunal communities recorded from Lake Connewarre support the future use of the meiofauna as a better system to assess changes to the lake benthos.

### *8.6.4 Foraminifera*

Coulson's (1935) report on the geology of Lake Connewarre listed 17 species of foraminifera (identified by Parr) which were collected from sediment bores taken from the shores and the floor of the lake. All forms ranged from Pleistocene to Recent in age, with all but two species recognised as being typically marine, thus providing evidence that saline water entered the lakes during the long period of siltation.

In 1945, Parr (1945) identified 142 Recent (modern) foraminiferal species, collected in 1932-1933 by Baragwanath and Baragwanath. Samples were collected from the sandy western shores of the lower Barwon estuary, between "20 and 30 chains" (400-600 m) upstream from the mouth. Parr noted the difficulty in distinguishing Recent species from those originating from Tertiary sedimentary deposits due to the "perfectly preserved" condition of fossil species. Of the 142 Recent forms recognised, 14 taxa were described as new. Parr provides a detailed written description of most taxa accompanied by a set of plates in which an image of each test is shown.

A more recent study by Bell (1995) found 11 living foraminiferal species from Lake Connewarre and the lower Barwon. Of the 11 species, six were agglutinated and five were calcareous. Bell attributed the low abundance of foraminifera to the variable salinity within the lake, high turbidity, the absence of aquatic vascular plants and the potentially mobile substrate, environmental factors that are not conducive to the proliferation of foraminifers. Bell pointed out that foraminifers are sensitive to low levels of oxygen, which tend to develop with the decomposition of plant detritus in the bottom sediment. Bell also recommended further investigation of the "microenvironment" to understand the patchiness and variability of foraminifers with the lake. He flagged particle size, organic content, oxygen concentration of sediments, and phytoplankton and microbial production as foraminiferal food sources as important factors on which to concentrate research efforts.

## *8.7* Miscellaneous Faunal Groups

At the turn of the twentieth century Mulder (1904) examined the fossiliferous beds at Campbell's Point, calling it one of the principal locations in the Geelong region where "Eocene" fossils were to be found (they are now regarded as Miocene). He identified 422 invertebrate species, representing six identified phyla and classes. These included the taxa Polyzoa (Bryozoa; 260 species), Gastropoda (151 species), Lamellibranchiata (Bivalvia; 26 species), Scaphopoda (three species), Pteropoda (one species) and Palliobranchiata (Brachiopoda; one species). According to Mulder, his was not the first study of the fossil beds of Campbell's Point. He recalled an investigation by Hall and Pritchard approximately eleven years earlier, who presented their findings before the Royal Society of Victoria in March, 1893.

Another survey of these beds by Stach (1933) in the early 1930s has also contributed to the fossil record of the area. Faunal groups found within the marls, approximately 2.4 m above the high water mark, included two species of Anthozoa, 13 species of Bryozoa, one of Brachiopoda, 16 of Pelecypoda (Bivalvia), one of Scaphopoda, 15 of Gastropoda, and one of Pteropoda. Stach provided a limited account of the locations of previous records of some of the species found, and concluded that the fauna appears to be most closely allied to that found at Muddy Creek, near Hamilton, which was regarded as being of early Miocene age.

During his sampling of deep sediment cores within Lake Connewarre and Reedy Lake, Coulson (1933) took the opportunity to record the names of the plants, invertebrates and birds that he observed in that area. He noted that a variety of molluscs was abundant on the samphire flats but only dead specimens were found in the "Big Lake" (presumably Lake Connewarre), blaming the demise of mollusc life in the lake on an increase in turbidity and the formation of ferrous sulfide. This idea has not been tested. Several mollusc species were found within the side channels and tidal flats around the lake. Twenty-one were listed, including *Salinator quoyama, Austrocochlea constricta, Turbo undulates, Polinices plumbea, Cominella lineolate, Mytilus planulatus and Cellana variegata*.

Gill & Collins (1983) proposed that the presence of marine fossils on the Moolap Lowland, north of Reedy Lake, provides evidence that this area was an ancient seaway from Corio Bay to Bass Strait, via the Reedy Lake to Lake Connewarre area. The fossils were characterised by a range of marine molluscs, dominated by *Anadara trapezia*, *Polinices* spp., *Katelysia rhytophora, Ostrea sinuate, Velacumantus australis* and *Hormomya erosa*.

Gill & Lane (1985) investigated the contents of an Aboriginal midden on Campbell's Point. Shells from the oysters *Anadara* and *Ostrea* yielded maximum ages 5270 years BP (corrected), the time of the mid-Holocene sea–level maximum. They concluded that the Aborigines harvested these marine species direct from Lake Connewarre when the sea had "direct access" to the lake and salinities were consistently higher. They also suggested that a retreat in sea level led to the extinction of the oyster beds within the lake, halting the Aboriginal harvest around 3620 years BP. Gill & Lane reported that this site was of particular archaeological significance as Aboriginal oyster middens were, until recently, considered to be limited to east Gippsland.

An analysis of arthropod composition and diversity in mangrove and saltmarsh habitats on the Barwon estuary at Barwon Heads and Ocean Grove between November 2000 and February 2001 identified the relationships between arthropod assemblages and vegetation characteristics (Travers 2001). Her results indicated that the number of floral species, the density of vegetation, the degree of shading and the number of strata within the vegetation were significant factors that affected arthropod richness and diversity. Of the arthropod taxa that were unevenly distributed between the two vegetation zones, most tended to favour the mangrove habitat over saltmarsh habitat, suggesting that the structural characteristics of the mangrove shrubland was a prime factor.

Travers (2001) identified 31 species of arthropod in the Barwon river study. Twenty-three families and 10 orders were recognised from mangrove habitat, whilst 25 families (10 orders) were represented within the saltmarsh. Dipterans were found to be numerically dominant in both habitats, accounting for 86% and 47% of individuals within the mangrove and the saltmarsh vegetation respectively. The importance and health risks associated with mosquito borne diseases were briefly addressed. This is most relevant to the Barwon Estuary, where mosquito control is exercised regularly.

In 2002, Mondon et al. (2003) identified 18 and 25 taxa respectively during autumn and winter surveys of benthic macroinvertebrate communities in the Barwon estuary. This information was used to derive a biological indicator of estuarine health as part of the Western Victorian Estuaries

Classification Project. Although none of the taxa was listed in the report, values for species richness were ranked against those of other western Victorian estuaries. The Barwon estuary was ranked at 26 for the greatest number of taxa and 27 for highest species richness during autumn (from 34 estuaries sampled), and ranked 34 for the greatest number of taxa and 33 for highest species richness during winter/spring (from 40 estuaries sampled).

The Corangamite Wetland Inventory Database (Harding 2002) provides estimates of the number of macroinvertebrates found at 23 locations within and around the Lake Connewarre Complex and ranks the aquatic fauna values for macroinvertebrates as low, medium or high. The database provides a powerful way to collate, manage and report information regarding the characteristics, condition, constituent flora and fauna, threats and management options for wetlands within the Lake Connewarre Complex and other wetland systems within the region. An opportunity exists to expand the data set of flora, fauna and other ecological parameters of the Lake Connewarre Complex using this program.

## *8.8* Altona Skipper Butterfly

The Altona skipper butterfly (*Hesperilla flavescens flavescens*) is an insect species listed in accordance with Section 10 of the FFG Act 1988 (Department of Sustainability and Environment 2006). Areas of chaffy saw sedge (*Gahnia filum*) near Barwon Heads and Connewarre provide habitat and food source for this rare species (Crosby 1990). The larval form of the butterfly is solely dependent on the leaves of *Gahnia*. In his management plan for the species, Crosby provided details of the locations and conditions of these habitats and the status of the butterfly populations. One site 2 km west-southwest of Barwon Heads was in a poor state. The area was reported to have become weed-infested and desiccated. Although the colony was not surveyed, Crosby presumed that the colony was in a state of decline. At another site at Connewarre, Crosby reported a colony of unknown size on the southern and western sides of Lake Connewarre. He mentioned that the known colonies were on private land. However, these locations are close to that of the LCSGR, which supports significant expanses of *G. filum*. A recommendation by Crosby to survey these adjacent areas should be supported. Opportunities to search for other populations of *H. flavescens* are numerous where extensive areas of *G. filum* occur throughout other parts of the reserve, as indicated by Yugovic (1985).

Crosby (1990) identified potential threats to *H. flavescens* colonies, including:

1. atmospheric (e.g. herbicide) or surface (e.g. water borne) pollution
2. human interference (e.g. trampling, rubbish dumping and dust creation)
3. animal interference (e.g. livestock trampling or grazing)
4. fire
5. altered hydrology (e.g. wetland drainage or excessive flooding), and
6. weed invasions.

An additional issue, habitat loss via land use changes (e.g. agricultural, domestic or industrial development) was not listed in the management plan, and may be a threat for colonies within the Lake Connewarre Wetland Complex, particularly on private land. Another factor not raised was the effect of climate change on coastal *H. flavescens* colonies. Saltmarsh plants with a greater tolerance for tidal inundation may displace adjacent *G. filum* sedgelands with a minor rise in mean sea level.

## *8.9* Summary and Issues

- Reports of birds, fish and several invertebrate groups (including plankton and meiofauna) have provided a good indication of what species inhabit the Lake Connewarre Complex. Surveys targeting mammals, reptiles and frogs are few and the current records of past and present species may not accurately represent these faunal groups within the area.

- An opportunity exists to expand the data set of fauna within Lake Connewarre Complex from references reviewed in this document.
- Future field surveys should target the mammal, reptile, frog and invertebrate groups to improve the inventory of fauna and clarify the level of biodiversity of the area.
- There is a distinct paucity of research reports that address the ecology of wetland fauna within the Lake Connewarre Complex.
- Changes in the assemblage composition of the lake biota in the future will depend on the tolerance to changed conditions of the estuarine species present. Eco-physiological studies are essential to predict the consequences of climate change.
- It is anticipated that additional physiological stress, such as from turbidity or pollution, could be detrimental to species that already devote much metabolic energy to surviving challenging conditions. Such marginal species would probably be replaced by a lower-diversity assemblage of more opportunistic and ephemeral 'weed' species in the lake.
- Opportunities exist to test the use of indicator faunal species or groups (e.g. meiofauna) as an early warning to the onset of ecosystem disturbance and decline associated with pollution, climate change, altered flows, salinity changes and other impacts.

# 9 Water quality and environmental flows

In keeping with the project brief, information on surface water hydrology is limited to a discussion on surface water quality and environmental flows. In both cases, there is a general paucity of information available on the topics. Most information on surface water hydrology relates to the management of flows in the Barwon River and the construction of breakwaters and channels etc.

## *9.1* Water quality

Very few studies have looked at the water quality within the Lake Connewarre Complex. To date, the most comprehensive investigation has been carried out by Sherwood et al. (1988). From March 1986 to March 1987, a range of physicochemical parameters was measured as part of their investigation of the potential ecological effects of reduced flows from the Barwon River on the estuarine wetland system. Six physicochemical characteristics were measured *in situ*, whilst samples were collected for 11 laboratory-based analyses. Table 9-1 shows a list of all physicochemical parameters measured during the investigation.

| **Physical Parameters** | **Chemical Parameters** |
|---|---|
| Temperature *(i.s.)* | Salinity *(i.s.)* |
| Secchi Depth (water clarity) *(i.s.)* | Dissolved Oxygen *(i.s.)* |
| True Colour | Total Nitrogen |
| Total Suspended Solids | Total Kjeldahl Nitrogen |
| Fixed Solids | Total Oxidised Nitrogen |
| Volatile Solids | Total Phosphorus |
| Water Velocity *(i.s.)* | Total Organic Carbon |
| Water Level/Water Depth *(i.s.)* | Dissolved Organic Carbon |
| | Particulate Organic Carbon |

*(i.s.) - indicates in situ measurement*

*Table 9-1. Physical and chemical parameters measured and assessed between March 1986 to March 1987.*

*(Source: Sherwood et al. 1988)*

The following is a summary of some of the results of Sherwood et al. (1988), with comparisons from other investigations.

### *9.1.1 Salinity*

Salinity varied significantly in Lake Connewarre throughout the study period (less than I.0 ppt to more than 28 ppt). This compares with surface salinity measured in 2002 (9.07 ppt to 32.5 ppt) (Mondon et al. 2003). Salinity was lowest between July and October 1986, when river discharge was at its highest for that period, and peaked in March 1986, at the beginning of the study (Sherwood et al. 1988). The lake exhibited “appreciable” stratification in both winter (June 1986) and summer (December 1986), whilst variations in salinity were negligible with depth when measured in March 1986 and February 1987. Sherwood et al. (1988) established a mathematical relationship between monthly discharge of the Barwon River (obtained from McIntyre’s Bridge) and the salinity from Lake Connewarre. The following linear equation represents that relationship.

$$\log_{10} Q = (4.86 \pm 0.19) - (1.08 \pm 0.16) \log_{10} S$$

where Q = monthly discharge (x $10^3$ $m^3$) and
S = salinity at the middle of the north arm of the lake (station v from Sherwood et al. 1988).
Uncertainties are standard deviations and the regression is highly significant.

Sherwood et al. (1988) admit to the “crudeness” of this mathematical analysis and argue that the usefulness of the equation is dependent on the acceptability of the uncertainties of the two constants.

Measured salinities within Reedy Lake and the Barwon River (above the lower breakwater) never exceeded 3 ppt during the course of their study, with river levels generally about 1 ppt lower than Reedy Lake. These results suggested that the open waters of Reedy Lake were fairly well mixed. Salinities were lowest in late September–October, corresponding with maximum river discharge. It was concluded that increases in salinity during summer and autumn may be a response to evaporation.

A recent investigation to determine the environmental flows for the Barwon River (Lloyd Environmental 2005) identified the saline water table beneath Reedy Lake as an important factor in influencing the lake’s floristics. Manipulation of surface water levels can affect the depth of the underlying water table and hence govern the proliferation of flora with certain salinity tolerances.

Waters within the channel of the lower Barwon estuary were found to be generally well mixed. The combination of the tidal amplitude and a narrow sinuous channel generates sufficient turbulence to break down any density stratification that may develop. Stratification due to salinity differences may occasionally occur during periods of low water velocity, such as near “slackwater” and during tides of low amplitude (Sherwood et al. 1988).

The section of the Barwon upstream of Lake Connewarre to the lower breakwater tends to be well mixed and low in salinity during high discharge periods. A salt wedge develops when river discharge is at or below 50–100 Ml day$^{-1}$.

Mondon et al. (2003) detected stratification within the lower and mid-estuary during winter, but found the waters well mixed in autumn. This partially corroborates the findings of Sherwood et al. (1988). However the terms lower and mid-estuary used by Mondon et al. may not correspond with those chosen by Sherwood et al. which make it difficult to draw direct comparisons on these and other parameters.

### *9.1.2 Temperature*

Temperature extremes within the Lake Connewarre Complex were 7.2 ºC and 27.0 ºC, with minimum temperatures occurring in June and July and maximum temperatures in February and March. Local air temperature appears to be a dominant factor in controlling water temperature within the system. Spatial variations in water temperature can be attributed to varying degrees of marine influence and a wide range of water depths.

### *9.1.3 Secchi depth*

The measure of Secchi depth provides an indication of the extent of light transmission through a water column and is a function of the concentrations of dissolved and particulate matter in the water, especially the latter. Sherwood et al. (1988) used this method to show that wind speed affected the turbidity of Lake Connewarre by resuspending sediments via wave action. The north-east arm of the lake often had the lowest mean Secchi depth. Its high level of exposure and being the most leeward region of the lake during the prevailing south westerly winds were the likely reasons for this.

### *9.1.4 Dissolved oxygen*

Dissolved oxygen levels ranged from 5.5 mg l$^{-1}$ (64 % saturation) to 17.0 mg l$^{-1}$ (180 % saturation) throughout the wetland complex, although most readings fell between 7.5 mg l$^{-1}$ and 11.5 mg l$^{-1}$. Severe oxygen depletion resulted within the deeper water below the lower breakwater during the autumn of 1987. The development of a salt wedge at this point was identified as the cause.

Oxygen replenishment was satisfactory throughout other parts of the wetland complex due to the combination of photosynthetic activity and turbulence (due to winds, tides and river discharge). Rooney (1984 in Sherwood et al. 1988) found similar results during a study between 1982 and 1984.

Mondon et al. (2003) detected hypoxia within the bottom waters at the mouth, lower and mid-sections of the estuary in autumn 2002, even though waters were reported to be mixed during this period.

### 9.1.5 Suspended solids

Suspended solids may contribute to a substantial proportion of the total sediment input into the wetland complex. This is due to the impedance of the river bedload by the upper and lower breakwaters. Sea water (< 10 mg $l^{-1}$) delivered by incoming tides should dilute suspended solids concentrations as it mixes with river water, a phenomenon previously observed in other south-west Victorian estuaries (Sherwood et al. 1988, after Sherwood 1985). Very high suspended solids concentrations in Lake Connewarre were associated with wind-generated turbulence, whereas Reedy Lake was less affected by winds due to a heavily vegetated floor and the wind-breaking affect of banks of emergent vegetation.

### 9.1.6 Total phosphorus

Total phosphorus concentrations tended to follow a trend similar to that for suspended solids. Values were highest in Lake Connewarre's north arm during high flow periods. A maximum concentration of 670 µg $l^{-1}$ was reached during the October 1986 flood. Phosphorus levels within the Barwon estuary were similar to those found in other estuaries. Mean total phosphorus concentration for Reedy Lake was 94 µg $l^{-1}$.

### 9.1.7 Total oxidised nitrogen (nitrates/nitrites) and total Kjeldahl nitrogen

Most oxidised nitrogen would occur as nitrates due to the well oxygenated character of the Lake Connewarre Complex's waters (Sherwood et al. 1988). High concentrations of oxidised nitrogen were associated only with the river channel above Lake Connewarre or during high flows. Levels were normally below 15 µg $l^{-1}$ throughout the wetlands complex.

Total Kjeldahl nitrogen concentrations varied in 1986-87 from around 130 µg $l^{-1}$ (near the estuary mouth) to over 1500 µg $l^{-1}$ in other parts of the wetlands complex. Consistently high values in Reedy Lake may be associated with biological inputs (possibly bird guano; Sherwood et al. 1988).

Based on nitrogen and phosphorus concentrations, Reedy Lake and Lake Connewarre were considered eutrophic. Reedy Lake had a tendency to be phosphorus-limited whilst other areas of the wetland system may be nitrogen-limited. The latter result is in contrast to the findings of Mondon et al. (2003) who found that the estuary was phosphorus-limited in autumn and winter of 2002. In 2002, total phosphorus and total nitrogen exceeded the ANZECC trigger levels on the two occasions that they were measured (Mondon et al. 2003). The Barwon estuary was ranked 16th best estuary out of 41 and 45 west Victorian estuaries in summer/autumn and winter/spring of 2002, respectively, in terms of its total nitrogen concentrations (Mondon et al. 2003). The Barwon ranked 15th and 20th against the same estuaries for total phosphorus. In all instances total nitrogen and phosphorus concentrations were a quarter of those of the worst ranked estuaries.

### 9.1.8 Organic carbon and colour

Dissolved organic carbon values in the river above Lake Connewarre ranged from 6.0 mg $l^{-1}$ to 20.4 mg $l^{-1}$ during high flows in 1986-87, consistent with concentrations throughout the rest of the estuary (Sherwood et al. 1988). During late summer and autumn, when flows were reduced, concentrations were commonly below 1 mg $l^{-1}$ in Lake Connewarre and the lower estuary. Concentrations in Reedy Lake were generally higher than other locations within the estuary, with a maximum value of 25.7 mg $l^{-1}$ recorded. Water colour readings showed similar trends to those for dissolved organic carbon, providing a secondary indicator for dissolved organic carbon.

Particulate organic matter constituted 10–20% of the suspended solids for 33 of 48 samples collected, with levels up to 46% in the upper estuary during low flows. Maximum concentrations of particulate organic matter of 25 to 30 mg $l^{-1}$ in Lake Connewarre were due to resuspension of bottom sediments containing about 12% organic matter. A mean ratio of dissolved organic carbon to particulate organic carbon (assumed to be 50 % of particulate organic matter) of 3.5 (with a standard deviation of 3.1) was found for all samples. This ratio is lower than that generally found for lakes and streams (Wetzel 1975, cited in Sherwood et al. 1988) and appears to be due to high levels of particulate organic carbon rather than low levels of dissolved organic carbon.

### *9.1.9 Correlation of chemical parameters*

Sherwood et al. (1988) were able to correlate various physicochemical parameters. Apart from the obviously related ones (e.g. Kjeldahl nitrogen and total nitrogen; suspended solids and particulate organic matter), other correlations were identified and discussed. These included:

- Kjeldahl nitrogen and salinity (r = -0.89)
- Kjeldahl nitrogen and dissolved organic carbon (r = 0.83)
- Salinity and dissolved organic carbon (r = -0.82), and
- Total phosphorus and particulate organic matter (r = 0.80).

### *9.1.10 Water quality guidelines*

Various water quality parameters of Australian marine, estuarine and freshwater ecosystems can be assessed against the national water quality guidelines developed by the *Australian and New Zealand Environmental Conservation Council* and the *Agriculture and Resource Management Council of Australia and New Zealand* (ANZECC and ARMCANZ 2000). Waters in Victoria can also be compared to the *Environment Protection Authority Victoria* (EPA) water quality objectives (Environment Protection Authority Victoria 2001, 2003). Mondon et al. (2003) used the ANZECC and ARMCANZ guidelines to gauge the quality of water within the Barwon River estuary with respect to nitrogen and phosphorus.

Further opportunities exist to gauge existing and future water quality data collected for the Lake Connewarre Wetland Complex against the guidelines cited above as a way of tracking long-term changes in wetland condition. The real value of this mode of water quality assessment and monitoring is in its role in signalling events where water quality parameters approach or exceed the trigger values of the guidelines. Timely and appropriate responses can therefore be employed to avert deleterious ecological conditions or to reinstate healthy conditions once unacceptable levels are reached.

## *9.2* Environmental flows

Despite extensive investigation, monitoring and research on the surface water hydrology of the Barwon River over the past century, there is little literature on environmental flows. This is not surprising as the concept of maintaining a river flow to sustain environmental values is relatively modern. The earliest concern for flows required to maintain environmental value were in relation to utilising Reedy Lake as a Game Reserve in the early 1960s (refer to Sections 2.5.2 & 2.5.3).

A draft document by Sherwood (2005) examines the environmental flow needs of the Barwon Estuary Complex taking into consideration both the river system and marine tidal influence. The document draws on the Sherwood et al. (1988) report to summarise the current estuary condition as well as the flow-related environmental risks. The report makes five draft management recommendations which have been considered and partially adopted in the following reviews.

The most recent review of environmental flow requirements was that by the Environmental Flows Technical Panel (EFTP), and jointly reported by Lloyd Environmental Pty, Ecological Associates Pty Ltd, and Fluvial Systems Pty Ltd (EFTP 2005a,b, 2006). The Barwon River Environmental Flows Project has recommended the flows required to achieve specific ecological objectives. The study used the FLOWS method for determining the environmental water requirements (DNRE 2002), which involves collection and review of data from the literature, field assessments, hydraulic modelling and community consultation. The entire Barwon River Basin was examined.

This comprehensive review was reported in three components:

**Site Paper (undated; electronic copy file dated 6/7/05).**

This is a 40-page document providing an overview of the Barwon River system, its flow-dependent assets, and the selection of reaches and sites for study. In regard to the Lake Connewarre Complex, the report states that the aim is to sustain the current freshwater and estuarine habitats, rather than restore the system to its natural (i.e. pre-regulated) condition. Among the assets specific to the Lake Connewarre Complex the report lists:

- fish and waterbird populations of the internationally significant, and Ramsar-listed, estuary complex;
- reedy vegetation communities on Reedy Lake;
- submerged marine aquatic macrophytes (*Zostera marina* and *Ruppia maritima*) in Lake Connewarre; and
- saltmarsh communities fringing Lake Connewarre.

**Issues Paper (August 2005; electronic copy file dated 5/9/05).**

A 138-page document presents the preliminary assessment of the Barwon River's physical and ecological assets requiring protection or promotion. The report contains a comprehensive analysis of the values associated with the two reaches of the Lake Connewarre Complex study area: Reach 4 – Geelong, from the Moorabool River junction to the lower Breakwater (p. 92), and Reach 5 – Estuary, including Salt Swamp, Hospital Swamp, and Reedy Lake (pp. 93-99).

The existing environmental flow rules are documented along with the preliminary recommendations for changes to these rules. Extensive hydraulic modelling (using REALM) was undertaken by SKM (2005) specifically for this project, and the technical reporting of this modelling makes up most of this report (pp. 7 – 75).

**Final Report – Flow Recommendations (February 2006; electronic copy dated 19/2/06)**

The final report is a 70-page document which includes the conclusions and recommendations of the investigation. For Reach 4 – Geelong, the report tabulates the flow objectives tabulated over page (Table 9-2).

The report concludes that the recommendations for this reach are mostly met with current flows, with the exception of bankfull flows. Despite this fact, the study concludes that any further reductions in the frequency or duration of the flow events will result in a decline of values in this reach.

For Reach 5 – the Barwon Estuary, the report devotes 13 pages (pp. 50 - 63) to a discussion of the requirements for flows to the individual components of the complex, viz: Salt Swamp, Hospital Swamp, Reedy Lake, and Lake Connewarre including the estuarine sections of the lower river channel.

These recommendations are discussed in the following sections.

| Flow | | | | Rationale |
|---|---|---|---|---|
| Season | Peak Magnitude (Mean Daily) | Frequency | Total Event Duration | |
| summer | low flow 8 Ml day$^{-1}$ | | | 4a Low flows sustain the macroinvertebrate community in summer |
| summer | low flow freshes 250 Ml day$^{-1}$ | 2 events per year | 14 days | 5a Avoid prolonged stratified conditions in pools<br>2k Grayling breeding trigger |
| winter | baseflow 80 Ml day$^{-1}$ | | | 1e Seasonal emergent macrophyte growth<br>2j Permanent deep pool (min depth 3 m) for grayling<br>2l Connecting flow between pools for grayling<br>2m Connecting flow to estuary<br>4d Support main growth and reproductive season for macroinvertebrates in spring |
| winter | high flow freshes 4,153 Ml day$^{-1}$ | 4 per season | 6 days | 1b Growth and recruitment of riparian shrubby vegetation<br>1f Growth and recruitment of floodplain woodland vegetation<br>1h Opportunistic aquatic plant growth in flooded billabongs<br>3g Scour sediments from base of pools<br>3d Maintain floodplain channels and inlets<br>2b Inundate floodplain vegetation for dwarf galaxias breeding<br>4b Extend habitat for aquatic macroinvertebrates |
| winter | bankfull flows 40,000 Ml day$^{-1}$ | Every 1.2 year | 16 days | 3c Maintain channel form and key physical habitat features<br>3e Downstream sediment transport |

*Table 9-2 Environmental flow objectives for Reach 4 – Geelong.*

*source: EFTP 2006, page 39.*

### 9.2.1 *Reedy Lake*

The study concluded that Reedy Lake does not achieve the five objectives identified, *viz*:

- the lake should support a diverse range of waterfowl, reed-dependent birds, fish-eating birds and large and small waders;
- the lake should support a range of aquatic plant communities including open-water, semi-emergent macrophytes and emergent macrophytes;
- carp populations should be minimised;
- water should have sufficient clarity to support the growth of submerged macrophytes; and
- the lake should support waterfowl hunting in late autumn and early winter.

Three water management regimes are proposed which would result in:

- flooding in early winter and drying out in mid-spring before the main growing season of reeds;
- exclusion of reeds from the central area by saline groundwater, by flooding that is too deep for them in spring and by the absence of flooding in their main summer growth period;
- a drying phase to control exotic fish species and allow nutrient processing in the wetland bed;

- flooding of the central lake area to a depth of more than 1 m for three to six months, in which would grow emergent and semi-emergent water plants like milfoil, *Potamogeton*, *Triglochin* and *Lepilaena*. This will allow for aquatic invertebrates and fish populations to breed and expand with Reedy Lake;
- reeds would persist, but in a zone near the seasonal upper limit of water levels in winter and spring; and
- high-level intermittent flooding in winter and spring by rainfall and river flows every two or three years to allow extensive flooding, aquatic habitat creation and fish breeding events.

The report notes that infrastructure improvements are required to achieve the objectives.

### 9.2.2 Hospital Swamp

Hospital Swamp comprises five basins which receive water from the Barwon River and estuary and from local runoff. In general, the current water regime supports the desired ecological communities. This involves:

- maintenance of a saline water table at or near the surface of the wetland bed. This will allow some areas of permanent low-level pools providing fish habitat over summer;
- freshwater inundation between June and November for a period of at least three months in most years to a depth of more than 0.4 m to support the growth of submerged aquatic plants such as *Lilaeopsis*, *Potamogeton* and *Ruppia*;
- freshwater inundation for two to four months to an elevation of 0.5 m AHD in winter and spring in most years to support the growth of emergent aquatic macrophytes such as *Phragmites australis* and the creation of extensive aquatic habitat, to stimulate fish breeding, and to enable recruitment of fish larvae;
- intermittent inundation (events of one to two weeks, two to four times per year) of the *Bolboschoenus* sedgeland and to enable extensive breeding events of fish such as galaxiids within the sedgelands;
- drawdown in November or December in most years to provide a growing opportunity for lake bed herbland species; and
- drawdown of the wetland in late summer and all of autumn to maintain the salinity of soil water and to restrict emergent macrophytes to the wetland fringe.

### 9.2.3 Salt Swamp

Salt Swamp receives runoff from a local catchment and rarer flooding events when the estuary spills into the basin. The study found that the swamp supports a diverse and intact vegetation native community and will continue to do so with the following water regime:

- a saline water table that lies at or near the surface of the wetland bed;
- drying of the wetland bed in summer and autumn to maintain the dominance of *Wilsonia* spp. by curtailing the growth of aquatic plants and providing a recovery period for *Wilsonia* spp.; and
- flooding the wetland to the limit of the *Wilsonia* herbfield on an annual or biannual basis for four to six months to provide surface water and soil water and salinity requirements for *Wilsonia* spp. and to provide growing conditions for aquatic plants (e.g. *Ruppia maritima*). This will also create habitat, trigger breeding and allow for recruitment of macroinvertebrate and fish species.

In addition, flooding of the fringing shrublands and sedgelands for one to two months every three years was recommended for the breeding of native fish species.

#### *9.2.4 Lake Connewarre including the estuary*

Lake Connewarre is part of the Barwon estuary and the dynamic changes in water levels and salinity are required to maintain the diversity of species. The suggested water regime for the lake is:

- complete flushing during winter to maintain salinities at or below seawater;
- spring flushes of freshwater from upstream to lower salinity and flood marginal zones of the lake to trigger fish breeding and recruitment;
- low discharge in autumn to minimise flushing; and
- flows over the fishway at the lower breakwater to enable fish movement along the lower Barwon.

The following flow recommendations were made in the report:

- For late winter to early spring: A flow of at least 600 ± 200 Ml day$^{-1}$ measured at McIntyres Bridge (Geelong) should be maintained for at least three months in late winter/early spring (between July and October) as a flushing flow to maintain freshwater conditions. This flow should occur at least once annually.
- For summer and autumn: Salinity in Lake Connewarre should not exceed 35 ppt during summer and autumn low flow conditions and this maximum level should not be maintained for more than two months. The minimum environmental flow needed to achieve this is 30 ± 10 Ml day$^{-1}$ at McIntyres Bridge.
- In relation to flow variability: Flows less than the minimum flow established in Recommendation 2 (including cease-to-flow conditions) should be allowed to occur at their natural frequency and timing. Periods of higher flow should occur during summer and autumn at their natural frequency and timing to mimic natural freshes. The frequency and timing of these flows, and any independent rules relating to this recommendation, will need to be formulated via further analysis of modelled flow data.
- In relation to flow connectivity: Fish passage should be provided to allow migration of diadromous species between freshwater and the estuary/sea.

### *9.3* Summary and Issues

- The majority of data and information on water quality and environmental flows are sourced from the studies by Sherwood et al. (1988) and the Environmental Flows Technical Panel (2005a,b, 2006).
- The projected effects of climate change in south-eastern Australia may be expected to increase the fluctuations of many physical and chemical variables that characterise the Lake Connewarre Complex. These variables include salinity, temperature, dissolved oxygen concentration, surface water flows, groundwater flows, erosion and sedimentation.
- There is a general lack of data on water quality and environmental flows which could be addressed by regular sampling and monitoring of the waters of the Lake Connewarre Complex to determine accurately changes with time.
- The relationships amongst physical, chemical and biological components of the wetlands system are largely unknown. These relationships need to be investigated and established so that the optimal conditions for floral and faunal species can be determined.
- To maintain the environmental values of the Lake Connewarre Complex, guidelines based on physicochemical parameters and their rate of change are required to estimate trigger values beyond which interventionist management may be advised, such as the adjustment of water flow through the wetlands.
- It may be necessary to review the existing Environmental Flows investigation as the national methodology for estuarine environments is further developed.

# 10 Wetland Characterisation, Condition Assessments and Management Planning

Several organizations and agencies have established inventories and characterised wetlands and estuaries, and in most cases assessed their environmental condition. These programs have occurred at international, national, state, regional or local scales. Their inventories and assessments usually provide limited information about the physicochemical and biotic characteristics of each wetland or estuary, and its values, uses, threats and management. The Barwon River estuary and its associated wetlands have been incorporated into some of these programs and included in their respective documents. Documents that include the Barwon River estuary and/or the Lake Connewarre Complex are listed below:

1. The Estuary Assessment Framework for Non-pristine Estuaries (National Land and Water Resource Audit: Barwon River condition assessment report) (Cooperative Research Centre for Coastal Zone Estuary and Waterway Management 2001).
2. Western Victorian Estuaries Classification Project (Mondon et al. 2003).
3. A Directory of Important Wetlands in Australia, Second Edition (Australian Nature Conservation Agency 1996).
4. The Corangamite Wetland Inventory Database (Harding 2002).
5. A Directory of Wetlands of International Importance (Wetlands International [online] 2007).
6. Initial Contact with Landholders Adjoining the Lake Connewarre State Game Reserve: Wetland Site Assessment and Landholder Survey (Billows 2003).

Combined, these documents provide a mixture of general and detailed information on the Lake Connewarre Complex that can be used to guide the management of the wetlands.

Several management documents refer to the ecological values of the Lake Connewarre Complex (or its components) in varying degrees of detail. These include:

- Corangamite Regional Catchment Strategy, 2003–2008 (CCMA 2003)
- Corangamite Wetland Strategy 2006–2011 (Sheldon 2006)
- Corangamite Regional Nutrient Management Plan 2000 (Adams 2000)
- Floodplain Management Strategy 2002 (CCMA 2002)
- Corangamite Salinity Action Plan 2005–2008 (Nicholson et al. 2006)
- Corangamite River Health Strategy (CCMA 2004)
- Central West Victoria Estuaries Coastal Action Plan 2005 (Western Coastal Board 2005)
- Lake Connewarre State Game Reserve Management Plan (Department of Conservation and Natural Resources 1993)
- Port Phillip Bay (Western Shoreline) and Bellarine Peninsula Ramsar Site Strategic Management Plan (Department of Sustainability and Environment 2003)
- Geelong Wetland Strategy (CoGG 2007)
- Geelong Environmental Management Strategy 2006–2011 (CoGG 2006)

The *Lake Connewarre State Wildlife Reserve: A Whole of Government Review of Legislation and Policy* (Ryan 2005) reviews the range of provisions set out by Commonwealth, State and local governments that apply to the reserve.

# 11 Conclusions

This review has shown that the Lake Connewarre Complex has significant attributes which make it valuable as a natural asset, as recognised by its Ramsar status. The value of the lake and environs to the local and regional communities has probably been understated in its recent management, although the implementation of the Geelong Wetland Strategy and Corangamite Wetland Strategy should make amends. It is apparent that many community groups such as the Field and Game Association and the Geelong Field Naturalists have made an extraordinary contribution to maintaining the values of the Lake Connewarre Complex.

Overall, there are few published data and few studies that contribute to our understanding of contemporary processes or management issues in the Lake Connewarre Complex. In particular, there is a paucity of information on the interactions between the three hydrological systems – surface water, groundwater and marine waters. Very few data exist on water quality and sediment quality, and their relationships to ecosystem health. There has been relatively little information published about the biological components of the Lake Connewarre Complex compared with the geological components. The environmental history has been poorly documented compared to the social history, and should address the likely impacts of industrial, mining and urban development, in addition to river regulation and alterations to flow.

In geological terms, the Lake Connewarre Complex is a transient feature in a young and dynamic landscape. Over the past hundred thousand years, the landscape surrounding the complex has undergone vast changes due to massive variations in climate, river flows and sea levels. In the historical timeframe of the past 170 years, especially during the first century of settlement at Geelong, anthropogenic changes to land and water use have also resulted in landscape modifications. These have been at a smaller scale but accelerated rate, when compared to the natural changes. The landscape of the Lake Connewarre Complex today continues to be modified by both natural and anthropogenic processes.

These processes threaten the values and environmental integrity of the Lake Connewarre Complex. The manner of the threat presented by each process as identified in this review of the literature is summarised in Table 11-1.

| **Landscape process or issue** | **Significance for the values of the Lake Connewarre Complex** |
|---|---|
| Climate change | Predictive models and scenarios indicate temperature rises, less availability of water, more extreme climatic events, sea-level rises, more coastal storm surges and increased frequency of natural hazards. |
| Sea-level changes | Sea level rise may threaten the hydrology, water quality, sedimentation and ecosystems. Inundation would eliminate existing fringing mangrove habitat along the Barwon River. The recreational values of the lake complex may deteriorate. Marine incursion may increase the dispersal of the larvae marine species and result in a loss of freshwater species. |
| Changes in groundwater-surface water-marine water interactions | Changes in the dynamic 'balance' amongst the three water systems may threaten the environmental and social values of the complex. Changed surface water input will correspondingly change the saline groundwater levels and the position and form of the freshwater/saltwater interface. Ecosystem health may be threatened by these changes. |

| | |
|---|---|
| Low flows in the Barwon River and low lake levels. | Low flows and low lake levels change the hydrological balance and may affect water quality (less fresh water), reduce sedimentation and increase the fraction of fine-grained sediment. Ecosystem health may be threatened by these changes. |
| Surface water and groundwater extraction | Increased water extraction may change the water levels (depending on the volume extracted) and therefore alter the 'balance' between the systems, which in turn will alter the discharge into the lakes and threaten the environmental values. |
| Increased storm water disposal | Increased freshwater and contaminants can rapidly and temporarily change the water quality, with resulting degradation of ecosystem health. Synergistic effects with other pressures would constrain biodiversity. |
| Urban encroachment and land values | Encroachment may affect the surface water hydrology (increased runoff), hydrogeology (changes to groundwater recharge), environments (introduction of pest plants and animals; loss of habitat), visual amenity, access and recreational uses. |
| Increased turbidity of lake waters | The aquatic ecosystem may be threatened due to reduced primary production |
| Changed rate of sediment accumulation | Lake depth, water quality and aquatic organism food supply may change. |
| Sand-bar migration | Water flows, channel morphology, and erosion rates may change and threaten mangrove and/or seagrass ecosystems. |
| Closure of river mouth | Littoral, sublittoral and lacustrine environments may be threatened. Benthic and pelagic assemblages would change. |
| Increasing land and water salinity | Increasing salinity threatens numerous land, water, infrastructure and environmental assets. |
| Contamination of lake sediment | Contamination may be toxic to the environment if released or disturbed, especially if associated with acid sulfate soils. |
| Development of acid sulfate soils | Acid release would be toxic to the environment and constrain development. |
| Changes to species refugia | Changes to terrestrial and aquatic habitats may threaten individual species or an ecosystem. |
| Current and future management of the complex | Management is critical to all values associated with the complex. |

*Table 11-1 Landscape processes or issues and their corresponding threat to values.*

## *11.1* Recommendations

In collating the summaries at the end of each section of this report, the following general recommendations emerge.

a) Universities, research agencies and management authorities should contribute to and assist in the completion of inventory data sets for the Lake Connewarre Complex. In particular, regular monitoring of surface water levels and quality, groundwater levels and quality, sediment quality, and floral and faunal health would greatly assist in understanding the relationships amongst the physical, chemical and biological components of the system. Where possible, combine the various wetland/estuarine data sets into a central inventory/database where direct comparisons of common data can be made between Australian estuaries and coastal wetland complexes.

b) Universities, research agencies and management authorities should continue to collaborate on targeted research on environmental and social aspects of the Lake Connewarre Complex to improve sustainable management outcomes.

c) Managers of the Lake Connewarre Complex should establish and prioritise clear management targets that respond to threats based on robust data concerning wetland condition.

d) Update the Lake Connewarre State Game Reserve Management Plan (DCNR 1993).

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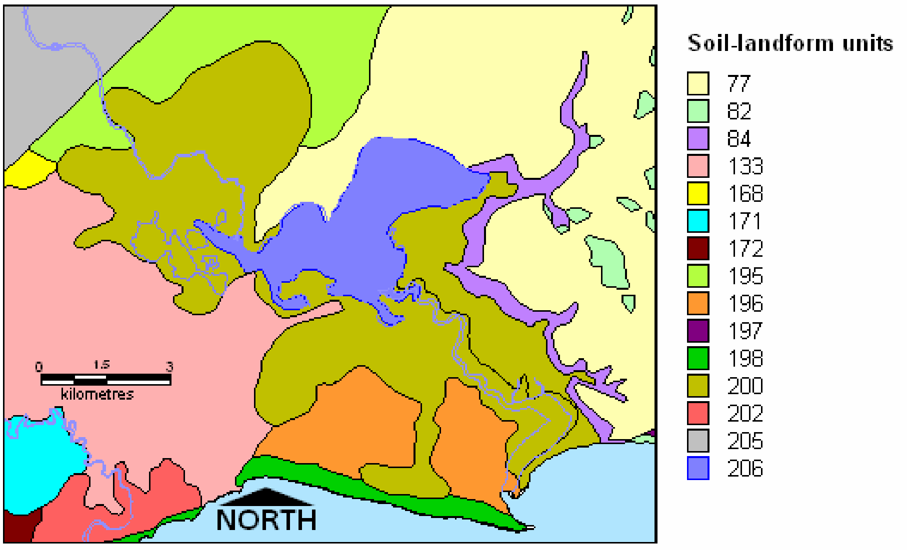
| VPRS | 44 | Unit 470 | Barwon River Survey |
| VPRS | 44 | Unit 8 | Survey of Tait's section |
| VPRS | 242 | Unit 27 | Connewarre petition |
| VPRS | 5714 | Unit 1030 | Closer Settlement File |
| VPRS | 242 | Unit 776 | Murtnaghurk Swamp |
| VPRS | 242 | Unit 498 | Moolap Swamp, shell |
| VPRS | 12011 | Unit 172 | State Wildlife Reserves |
| VPRS | 5357 | Unit 2365 | Survey north of Reedy |

Reedy Lake and Lake Connewarre, Rs 12158 current Crown Lands file, Geelong DSE.

# Appendix A Soil-landform descriptions



**Soil-landform units of the Lake Connewarre Complex region (Robinson et al. 2003)**

The detailed descriptions of each soil landform unit are included on the CD in the rear pocket of this report. The description for soil landform unit 200 is provided on the following pages as an example of those on the CD.

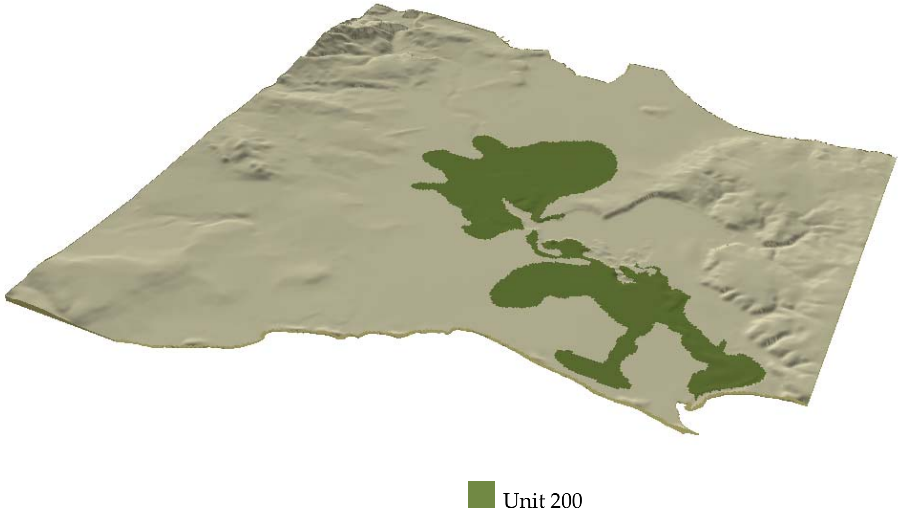
## Soil-landform unit 200

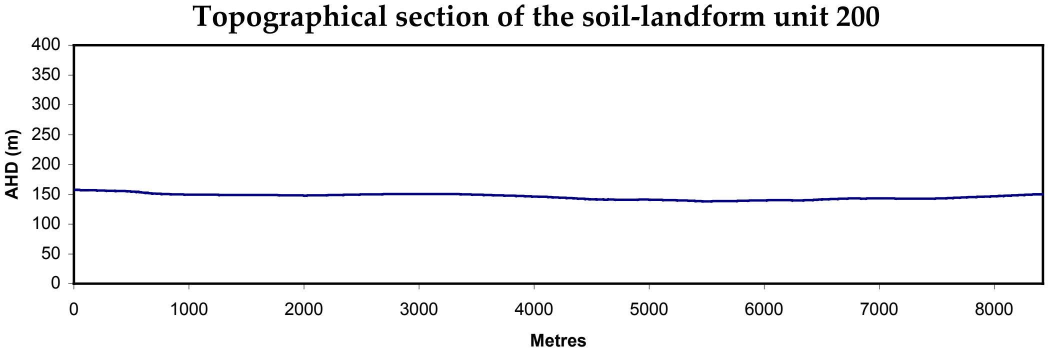
Area: 7186 ha
0.54% of CMA region

Across the dissected sedimentary plains of the Western Plains are numerous swamps and closed depressions that host a wide variety of flora and fauna. These permanent swamps have been identified as occurring south of Geelong on Recent clay, sand and gravels, coastal sand dunes and minor basalt. Many of the swamps have been cleared previously with some untouched by land clearance. Vegetation classes of these swamps include Coastal Saltmarsh, Reed Swamp, Plains Freshwater Sedge Wetland, Cane Grass-lignum Halophyllic Herbland and Calcarenite Dune Woodland. Land use is mainly restricted to grazing owing to the waterlogged state of soils in most years. Soils include the grey cracking clays and sandy soils that reflect Recent alluvium deposits. While waterlogging is the major limitation, salinity is also expressed at the surface in many of these swamps as spiny rush.

The Moolap Sunklands have a very diverse range of wildlife and habitats in this very unique wetlands within the Corangamite CMA region

Located west of Barwon Heads, this swamp forms part of the Moolap Sunklands. The vegetation most prominent here is the Reed Swamp class





Reed swamp vegetation class of the Moolap Sunklands

| *Component* | 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| *Proportion of soil-landform unit* | 2% | 38% | 40% | 20% |
| **CLIMATE** | | | | |
| Rainfall (mm) | Annual: 640 | | | |
| Temperature ($^{o}$C) | Minimum 9, Maximum 19 | | | |
| Precipitation: less than potential evapotranspiration | October–March | | | |
| **GEOLOGY** | | | | |
| Age and lithology | Quaternary clay, sand and gravel, coastal sand dunes and minor basalt | | | |
| Geomorphology | 6.2.5 Alluvium, alluvial terraces, floodplains and coastal plains of the Sedimentary Western Plains | | | |
| **LAND USE** | Uncleared: Nature conservation; water supply<br>Cleared: Cropping (cereal); sheep and beef cattle grazing | | | |
| **TOPOGRAPHY** | | | | |
| Landscape | Swamps and depressions associated with sedimentary plains | | | |
| Elevation range (m) | 4–148 | | | |
| Local relief (m) | 1–2 | | | |
| Drainage pattern | Deranged | | | |
| Drainage density (km/km$^2$) | 2.7 | | | |
| Landform | Alluvial plains | | | |
| Landform element | Dune | Depressions | Swamp | Undulating plain |
| Slope and range (%) | 2 (0–5) | 1 (0–2) | 1 (0–2) | 2 (1–4) |
| Slope shape | Convex | Straight | Straight | Convex |
| **NATIVE VEGETATION** | | | | |
| Ecological Vegetation Class | Coastal Saltmarsh (20.5), Reed Swamp (8.3%), Plains Freshwater Sedge Wetland (1.3%), Cane Grass-Lignum Halophyllic Herbland (1.2%), Calcarenite Dune Woodland (1.1%) | | | |
| **SOIL** | | | | |
| Parent material | Aeolian sediments; clay silt and sand | Sedimentary derived alluvium; clay silt and sand | Sedimentary derived alluvium; clay silt and sand | Sedimentary derived alluvium; clay silt and sand |
| Description (Corangamite Soil Group) | Grey and black clays (31) | Grey and black clays (31) | Grey and black clays (31) | Grey and black clays (31) |
| Soil type sites | SW37, CLRA15, CLRA35 | **SW37**, CLRA5, **SW39** | SW37, CLRA15, CLRA35 | SW37, CLRA15, CLRA35 |
| Surface texture | Light clay | Light clay | Light clay | Light clay |
| Permeability | High | Low | Low | Low |
| Depth (m) | >2 | >2 | >2 | >2 |
| **LAND CHARACTERISTICS, POTENTIAL AND LIMITATIONS** | Uniform expansive clays, high to very high water holding capacity and nutrient holding capacity depending on depth. Sodic subsoils, surface soils may be self-mulching. Low site drainage. Susceptibility to waterlogging. | Uniform expansive clays, high to very high water holding capacity and nutrient holding capacity depending on depth. Sodic subsoils, surface soils may be self-mulching. Low site drainage. Susceptibility to waterlogging. | Uniform expansive clays, high to very high water holding capacity and nutrient holding capacity depending on depth. Sodic subsoils, surface soils may be self-mulching. Very low site drainage. Susceptibility to waterlogging. | Uniform expansive clays, high to very high water holding capacity and nutrient holding capacity depending on depth. Sodic subsoils, surface soils may be self-mulching. Low site drainage. Susceptibility to waterlogging. |

## Appendix B Flora Information System (FIS) Search List for the Lake Connewarre Complex

(Search conducted May 2007)

| Common Name | Scientific Name | Family | FFG | EPBC | VROTS | Origin |
|---|---|---|---|---|---|---|
| Rounded Noon-flower | *Disphyma crassifolium* subsp. *clavellatum* | Aizoaceae | | | | |
| Galenia | *Galenia pubescens* var. *pubescens* | Aizoaceae | | | | * |
| Bower Spinach | *Tetragonia implexicoma* | Aizoaceae | | | | |
| Water Plantain | *Alisma plantago-aquatica* | Alismataceae | | | | |
| Crow Garlic | *Allium vineale* | Alliaceae | | | | * |
| Yellow Alstroemeria | *Alstroemeria aurea* | Alstroemeriaceae | | | | * |
| Trailing Hemichroa | *Hemichroa pentandra* | Amaranthaceae | | | | |
| Pepper Tree | *Schinus molle* | Anacardiaceae | | | | * |
| Annual Celery | *Apium annuum* | Apiaceae | | | | |
| Sea Celery | *Apium prostratum* subsp. *prostratum* | Apiaceae | | | | |
| Sea Celery | *Apium prostratum* subsp. *prostratum* var. *prostratum* | Apiaceae | | | | |
| Hemlock | *Conium maculatum* | Apiaceae | | | | * |
| Fennel | *Foeniculum vulgare* | Apiaceae | | | | * |
| Thread Pennywort | *Hydrocotyle capillaris* | Apiaceae | | | | |
| Australian Lilaeopsis | *Lilaeopsis polyantha* | Apiaceae | | | | |
| Sea Box | *Alyxia buxifolia* | Apocynaceae | | | | |
| Cape Pond-lily | *Aponogeton distachyos* | Aponogetonaceae | | | | * |
| White Bladder-flower | *Araujia sericifera* | Asclepiadaceae | | | | * |
| Bridal Creeper | *Asparagus asparagoides* | Asparagaceae | | | | * |
| Asparagus | *Asparagus officinalis* | Asparagaceae | | | | * |
| Onion Weed | *Asphodelus fistulosus* | Asphodelaceae | | | | * |
| Salt Angianthus | *Angianthus preissianus* | Asteraceae | | | | |
| Cape Weed | *Arctotheca calendula* | Asteraceae | | | | * |
| White Arctotis | *Arctotis stoechadifolia* | Asteraceae | | | | * |
| Aster-weed | *Aster subulatus* | Asteraceae | | | | * |
| Grass Daisy | *Brachyscome graminea* | Asteraceae | | | | |

| Common Name | Scientific Name | Family | FFG | EPBC | VROTS | Origin |
|---|---|---|---|---|---|---|
| Boneseed | *Chrysanthemoides monilifera* | Asteraceae | | | | * |
| African Boneseed | *Chrysanthemoides monilifera* subsp. *monilifera* | Asteraceae | | | | * |
| Spear Thistle | *Cirsium vulgare* | Asteraceae | | | | * |
| Fleabane | *Conyza* spp. | Asteraceae | | | | * |
| Water Buttons | *Cotula coronopifolia* | Asteraceae | | | | * |
| Slender Cotula | *Cotula vulgaris* var. *australasica* | Asteraceae | | | | |
| Stinking Hawksbeard | *Crepis foetida* subsp. *foetida* | Asteraceae | | | | * |
| Spanish Artichoke | *Cynara cardunculus* | Asteraceae | | | | * |
| Gazania | *Gazania linearis* | Asteraceae | | | | * |
| Trailing Gazania | *Gazania rigens* | Asteraceae | | | | * |
| Cretan Hedypnois | *Hedypnois cretica* | Asteraceae | | | | * |
| Ox-tongue | *Helminthotheca echioides* | Asteraceae | | | | * |
| Cat's Ear | *Hypochoeris radicata* | Asteraceae | | | | * |
| Prickly Lettuce | *Lactuca serriola* | Asteraceae | | | | * |
| Hairy Hawkbit | *Leontodon taraxacoides* subsp. *taraxacoides* | Asteraceae | | | | * |
| Creeping Cotula | *Leptinella reptans s.l.* | Asteraceae | | | | |
| Creeping Cotula | *Leptinella reptans s.s.* | Asteraceae | | | | |
| Coast Daisy-Bush | *Olearia axillaris* | Asteraceae | | | | |
| Jagged Fireweed | *Senecio biserratus* | Asteraceae | | | | |
| Annual Fireweed | *Senecio glomeratus* | Asteraceae | | | | |
| Scented Groundsel | *Senecio odoratus* var. *odoratus* | Asteraceae | | | | |
| Variable Groundsel | *Senecio pinnatifolius* | Asteraceae | | | | |
| Cotton Fireweed | *Senecio quadridentatus* | Asteraceae | | | | |
| Dune Groundsel | *Senecio spathulatus s.l.* | Asteraceae | | | | |
| Groundsel | *Senecio* spp. | Asteraceae | | | | |
| Rough Sow-thistle | *Sonchus asper s.l.* | Asteraceae | | | | * |
| Common Sow-thistle | *Sonchus oleraceus* | Asteraceae | | | | * |
| Garden Dandelion | *Taraxacum officinale* spp. agg. | Asteraceae | | | | * |
| Garden Dandelion | *Taraxacum* Sect. *Hamata* | Asteraceae | | | | * |

| **Common Name** | **Scientific Name** | **Family** | **FFG** | **EPBC** | **VROTS** | **Origin** |
|---|---|---|---|---|---|---|
| Salsify | *Tragopogon porrifolius* | Asteraceae | | | | * |
| Bathurst Burr | *Xanthium spinosum* | Asteraceae | | | | * |
| Pacific Azolla | *Azolla filiculoides* | Azollaceae | | | | |
| Bugloss | *Anchusa arvensis* | Boraginaceae | | | | * |
| Paterson's Curse | *Echium plantagineum* | Boraginaceae | | | | * |
| Twiggy Turnip | *Brassica fruticulosa* | Brassicaceae | | | | * |
| Buchan Weed | *Hirschfeldia incana* | Brassicaceae | | | | * |
| Oval Purse | *Hymenolobus procumbens* | Brassicaceae | | | | |
| Wild Radish | *Raphanus raphanistrum* | Brassicaceae | | | | * |
| Thread Water-starwort | *Callitriche hamulata* | Callitrichaceae | | | | * |
| Water Starwort | *Callitriche* spp. (naturalised) | Callitrichaceae | | | | * |
| Poison Pratia | *Lobelia concolor* | Campanulaceae | | | | |
| Common Mouse-ear Chickweed | *Cerastium glomeratum s.l.* | Caryophyllaceae | | | | * |
| Fine-leaved Sandwort | *Minuartia mediterranea* | Caryophyllaceae | | | | * |
| Four-leaved Allseed | *Polycarpon tetraphyllum* | Caryophyllaceae | | | | * |
| Lesser Sea-spurrey | *Spergularia marina s.s.* | Caryophyllaceae | | | | |
| Native Sea-spurrey | *Spergularia* sp. 1 | Caryophyllaceae | | | | |
| Swamp Starwort | *Stellaria angustifolia* | Caryophyllaceae | | | | |
| Native Orache | *Atriplex australasica* | Chenopodiaceae | | | | |
| Marsh Saltbush | *Atriplex paludosa* subsp. *paludosa* | Chenopodiaceae | | | r | |
| Hastate Orache | *Atriplex prostrata* | Chenopodiaceae | | | | * |
| Beet | *Beta vulgaris* | Chenopodiaceae | | | | * |
| Fat Hen | *Chenopodium album* | Chenopodiaceae | | | | * |
| Glaucous Goosefoot | *Chenopodium glaucum* | Chenopodiaceae | | | | |
| Sowbane | *Chenopodium murale* | Chenopodiaceae | | | | * |
| Grey Glasswort | *Halosarcia halocnemoides* subsp. *halocnemoides* | Chenopodiaceae | | | | |
| Blackseed Glasswort | *Halosarcia pergranulata* | Chenopodiaceae | | | | |
| Blackseed Glasswort | *Halosarcia pergranulata* subsp. *pergranulata* | Chenopodiaceae | | | | |
| Seaberry Saltbush | *Rhagodia candolleana* subsp. *candolleana* | Chenopodiaceae | | | | |
| Thick-head Glasswort | *Sarcocornia blackiana* | Chenopodiaceae | | | | |

| **Common Name** | **Scientific Name** | **Family** | **FFG** | **EPBC** | **VROTS** | **Origin** |
|---|---|---|---|---|---|---|
| Beaded Glasswort | *Sarcocornia quinqueflora* | Chenopodiaceae | | | | |
| Beaded Glasswort | *Sarcocornia quinqueflora* subsp. *quinqueflora* | Chenopodiaceae | | | | |
| Shrubby Glasswort | *Sclerostegia arbuscula* | Chenopodiaceae | | | | |
| Austral Seablite | *Suaeda australis* | Chenopodiaceae | | | | |
| Berry Seablite | *Suaeda baccifera* | Chenopodiaceae | | | | * |
| Coast Bonefruit | *Threlkeldia diffusa* | Chenopodiaceae | | | | |
| Large Bindweed | *Calystegia sepium* subsp. *roseata* | Convolvulaceae | | | | |
| Kidney-weed | *Dichondra repens* | Convolvulaceae | | | | |
| Narrow-leaf Wilsonia | *Wilsonia backhousei* | Convolvulaceae | | | | |
| Silky Wilsonia | *Wilsonia humilis* | Convolvulaceae | | | | |
| Round-leaf Wilsonia | *Wilsonia rotundifolia* | Convolvulaceae | | | | |
| Swamp Crassula | *Crassula helmsii* | Crassulaceae | | | | |
| Common Dodder | *Cuscuta epithymum* | Cuscutaceae | | | | * |
| Bare Twig-sedge | *Baumea juncea* | Cyperaceae | | | | |
| Salt Club-sedge | *Bolboschoenus caldwellii* | Cyperaceae | | | | |
| Club Sedge | *Bolboschoenus* spp. | Cyperaceae | | | | |
| Tall Sedge | *Carex appressa* | Cyperaceae | | | | |
| Sedge | *Carex* spp. | Cyperaceae | | | | |
| Poong'ort | *Carex tereticaulis* | Cyperaceae | | | | |
| Drain Flat-sedge | *Cyperus eragrostis* | Cyperaceae | | | | * |
| Common Spike-sedge | *Eleocharis acuta* | Cyperaceae | | | | |
| Small Spike-sedge | *Eleocharis pusilla* | Cyperaceae | | | | |
| Knobby Club-sedge | *Ficinia nodosa* | Cyperaceae | | | | |
| Chaffy Saw-sedge | *Gahnia filum* | Cyperaceae | | | | |
| Nodding Club-sedge | *Isolepis cernua* var. *cernua* | Cyperaceae | | | | |
| Swamp Club-sedge | *Isolepis inundata* | Cyperaceae | | | | |
| Little Club-sedge | *Isolepis marginata* | Cyperaceae | | | | |
| Club Sedge | *Schoenoplectus* spp. | Cyperaceae | | | | |
| River Club-sedge | *Schoenoplectus tabernaemontani* | Cyperaceae | | | | |
| Shiny Bog-sedge | *Schoenus nitens* | Cyperaceae | | | | |

| Common Name | Scientific Name | Family | FFG | EPBC | VROTS | Origin |
|---|---|---|---|---|---|---|
| Coast Beard-heath | *Leucopogon parviflorus* | Epacridaceae | | | | |
| Coast Bitter-bush | *Adriana quadripartita* | Euphorbiaceae | | | v | |
| Rare Bitter-bush | *Adriana quadripartita s.s.* (glabrous form) | Euphorbiaceae | f | | e | |
| Sun Spurge | *Euphorbia helioscopia* | Euphorbiaceae | | | | * |
| Petty Spurge | *Euphorbia peplus* | Euphorbiaceae | | | | * |
| Burr Medic | *Medicago polymorpha* | Fabaceae | | | | * |
| Sweet Melilot | *Melilotus indicus* | Fabaceae | | | | * |
| Narrow-leaf Clover | *Trifolium angustifolium* var. *angustifolium* | Fabaceae | | | | * |
| Drooping-flower Clover | *Trifolium cernuum* | Fabaceae | | | | * |
| Strawberry Clover | *Trifolium fragiferum* var. *fragiferum* | Fabaceae | | | | * |
| Cluster Clover | *Trifolium glomeratum* | Fabaceae | | | | * |
| White Clover | *Trifolium repens* var. *repens* | Fabaceae | | | | * |
| Gorse | *Ulex europaeus* | Fabaceae | | | | * |
| Common Vetch | *Vicia sativa* | Fabaceae | | | | * |
| Southern Sea-heath | *Frankenia pauciflora* var. *gunnii* | Frankeniaceae | | | | |
| Indian Fumitory | *Fumaria indica* | Fumariaceae | | | | * |
| Wall Fumitory | *Fumaria muralis* subsp. *muralis* | Fumariaceae | | | | * |
| Slender Centaury | *Centaurium tenuiflorum* | Gentianaceae | | | | * |
| White Sebaea | *Sebaea albidiflora* | Gentianaceae | | | | |
| Small-fruit Fan-flower | *Scaevola albida* | Goodeniaceae | | | | |
| Shiny Swamp-mat | *Selliera radicans* | Goodeniaceae | | | | |
| Hooded Water-milfoil | *Myriophyllum muelleri* | Haloragaceae | | | | |
| Lake Water-milfoil | *Myriophyllum salsugineum* | Haloragaceae | | | | |
| Amphibious Water-milfoil | *Myriophyllum simulans* | Haloragaceae | | | | |
| Water-milfoil | *Myriophyllum* spp. | Haloragaceae | | | | |
| Red Water-milfoil | *Myriophyllum verrucosum* | Haloragaceae | | | | |
| Tiny Star | *Hypoxis glabella* var. *glabella* | Hypoxidaceae | | | | |
| Wild Gladiolus | *Gladiolus undulatus* | Iridaceae | | | | * |
| One-leaf Cape-tulip | *Moraea flaccida* | Iridaceae | | | | * |
| Two-leaf Cape-tulip | *Moraea miniata* | Iridaceae | | | | * |
| Onion Grass | *Romulea rosea* | Iridaceae | | | | * |

| **Common Name** | **Scientific Name** | **Family** | **FFG** | **EPBC** | **VROTS** | **Origin** |
|---|---|---|---|---|---|---|
| Jointed Rush | *Juncus articulatus* | Juncaceae | | | | * |
| Green Rush | *Juncus gregiflorus* | Juncaceae | | | | |
| Sea Rush | *Juncus kraussii* subsp. *australiensis* | Juncaceae | | | | |
| Creeping Rush | *Juncus revolutus* | Juncaceae | | | r | |
| Rush | *Juncus* spp. | Juncaceae | | | | |
| Tiny Arrowgrass | *Triglochin minutissima* | Juncaginaceae | | | r | |
| Prickly Arrowgrass | *Triglochin mucronata* | Juncaginaceae | | | r | |
| Water Ribbons | *Triglochin procera s.l.* | Juncaginaceae | | | | |
| Common Water-ribbons | *Triglochin procera s.s.* | Juncaginaceae | | | | |
| Streaked Arrowgrass | *Triglochin striata* | Juncaginaceae | | | | |
| Australian Gipsywort | *Lycopus australis* | Lamiaceae | | | | |
| Horehound | *Marrubium vulgare* | Lamiaceae | | | | * |
| Common Duckweed | *Lemna disperma* | Lemnaceae | | | | |
| Tiny Duckweed | *Wolffia australiana* | Lemnaceae | | | | |
| Wire-leaf Mistletoe | *Amyema preissii* | Loranthaceae | | | | |
| Creeping Mistletoe | *Muellerina eucalyptoides* | Loranthaceae | | | | |
| Small Loosestrife | *Lythrum hyssopifolia* | Lythraceae | | | | |
| Salt Lawrencia | *Lawrencia spicata* | Malvaceae | | | r | |
| Mallow of Nice | *Malva nicaeensis* | Malvaceae | | | | * |
| Small-flower Mallow | *Malva parviflora* | Malvaceae | | | | * |
| Red-flower Mallow | *Modiola caroliniana* | Malvaceae | | | | * |
| Short-fruit Nardoo | *Marsilea hirsuta* | Marsileaceae | | | | |
| Nardoo | *Marsilea* spp. | Marsileaceae | | | | |
| Running Marsh-flower | *Villarsia reniformis* | Menyanthaceae | | | | |
| Lightwood | *Acacia implexa* | Mimosaceae | | | | |
| Coast Wattle | *Acacia longifolia* subsp. *sophorae* | Mimosaceae | | | | # |
| Hedge Wattle | *Acacia paradoxa* | Mimosaceae | | | | |
| Golden Wattle | *Acacia pycnantha* | Mimosaceae | | | | |
| Wirilda | *Acacia retinodes* | Mimosaceae | | | | # |
| Coast Wirilda | *Acacia retinodes* var. *uncifolia* | Mimosaceae | | | r | |
| Cape Wattle | *Paraserianthes lophantha* subsp. *lophantha* | Mimosaceae | | | | * |

| Common Name | Scientific Name | Family | FFG | EPBC | VROTS | Origin |
|---|---|---|---|---|---|---|
| Common Boobialla | *Myoporum insulare* | Myoporaceae | | | | # |
| River Red-gum | *Eucalyptus camaldulensis* | Myrtaceae | | | | |
| Bellarine Yellow-gum | *Eucalyptus leucoxylon* subsp. *bellarinensis* | Myrtaceae | f | | e | |
| Coast Tea-tree | *Leptospermum laevigatum* | Myrtaceae | | | | # |
| Moonah | *Melaleuca lanceolata* subsp. *lanceolata* | Myrtaceae | | | | |
| Desert Ash | *Fraxinus angustifolia* | Oleaceae | | | | * |
| Variable Willow-herb | *Epilobium billardierianum* | Onagraceae | | | | |
| Hairy Willow-herb | *Epilobium hirtigerum* | Onagraceae | | | | |
| Large Gnat-orchid | *Cyrtostylis robusta* | Orchidaceae | | | | |
| Leafy Greenhood | *Pterostylis cucullata* | Orchidaceae | f | V | v | |
| Dwarf Greenhood | *Pterostylis nana* | Orchidaceae | | | | |
| Grassland Wood-sorrel | *Oxalis perennans* | Oxalidaceae | | | | |
| Soursob | *Oxalis pes-caprae* | Oxalidaceae | | | | * |
| Wood Sorrel | *Oxalis* spp. | Oxalidaceae | | | | |
| Small-flower Flax-lily | *Dianella brevicaulis* | Phormiaceae | | | | |
| Black-anther Flax-lily | *Dianella revoluta s.l.* | Phormiaceae | | | | |
| Red-ink Weed | *Phytolacca octandra* | Phytolaccaceae | | | | * |
| Buck's-horn Plantain | *Plantago coronopus* | Plantaginaceae | | | | * |
| Ribwort | *Plantago lanceolata* | Plantaginaceae | | | | * |
| Greater Plantain | *Plantago major* | Plantaginaceae | | | | * |
| Yellow Sea-lavender | *Limonium australe* | Plumbaginaceae | | | r | |
| Brown-top Bent | *Agrostis capillaris s.l.* | Poaceae | | | | * |
| Creeping Bent | *Agrostis stolonifera* | Poaceae | | | | * |
| Southern Swamp Wallaby-grass | *Amphibromus neesii* | Poaceae | | | | |
| Swamp Wallaby-grass | *Amphibromus* spp. | Poaceae | | | | |
| Common Wallaby-grass | *Austrodanthonia caespitosa* | Poaceae | | | | |
| Bristly Wallaby-grass | *Austrodanthonia setacea* | Poaceae | | | | |
| Coast Fescue | *Austrofestuca littoralis* | Poaceae | | | r | |
| Spear Grass | *Austrostipa* spp. | Poaceae | | | | |
| Prickly Spear-grass | *Austrostipa stipoides* | Poaceae | | | | |
| Oat | *Avena* spp. | Poaceae | | | | * |

| **Common Name** | **Scientific Name** | **Family** | **FFG** | **EPBC** | **VROTS** | **Origin** |
|---|---|---|---|---|---|---|
| Large Quaking-grass | *Briza maxima* | Poaceae | | | | * |
| Lesser Quaking-grass | *Briza minor* | Poaceae | | | | * |
| Prairie Grass | *Bromus catharticus* | Poaceae | | | | * |
| Great Brome | *Bromus diandrus* | Poaceae | | | | * |
| Soft Brome | *Bromus hordeaceus* subsp. *hordeaceus* | Poaceae | | | | * |
| Fern Grass | *Catapodium rigidum* | Poaceae | | | | * |
| Pampas Grass | *Cortaderia selloana* | Poaceae | | | | * |
| Couch | *Cynodon dactylon* | Poaceae | | | | |
| Couch | *Cynodon dactylon* var. *dactylon* | Poaceae | | | | * |
| Cocksfoot | *Dactylis glomerata* | Poaceae | | | | * |
| Australian Salt-grass | *Distichlis distichophylla* | Poaceae | | | | |
| Panic Veldt-grass | *Ehrharta erecta* var. *erecta* | Poaceae | | | | * |
| Tall Fescue | *Festuca arundinacea* | Poaceae | | | | * |
| Yorkshire Fog | *Holcus lanatus* | Poaceae | | | | * |
| Mediterranean Barley-grass | *Hordeum hystrix* | Poaceae | | | | * |
| Barley-grass | *Hordeum leporinum* | Poaceae | | | | * |
| Sea Barley-grass | *Hordeum marinum* | Poaceae | | | | * |
| Coast Blown-grass | *Lachnagrostis billardierei* subsp. *billardierei* | Poaceae | | | | |
| Common Blown-grass | *Lachnagrostis filiformis* | Poaceae | | | | |
| Salt Blown-grass | *Lachnagrostis robusta* | Poaceae | | | r | |
| Hare's-tail Grass | *Lagurus ovatus* | Poaceae | | | | * |
| Wimmera Rye-grass | *Lolium rigidum* | Poaceae | | | | * |
| Rye Grass | *Lolium* spp. | Poaceae | | | | * |
| Tall Wheat-grass | *Lophopyrum ponticum* | Poaceae | | | | * |
| Chilean Needle-grass | *Nassella neesiana* | Poaceae | | | | * |
| Serrated Tussock | *Nassella trichotoma* | Poaceae | | | | * |
| Coast Barb-grass | *Parapholis incurva* | Poaceae | | | | * |
| Slender Barb-grass | *Parapholis strigosa* | Poaceae | | | | * |
| Paspalum | *Paspalum dilatatum* | Poaceae | | | | * |
| Water Couch | *Paspalum distichum* | Poaceae | | | | * |
| Kikuyu | *Pennisetum clandestinum* | Poaceae | | | | * |

| Common Name | Scientific Name | Family | FFG | EPBC | VROTS | Origin |
|---|---|---|---|---|---|---|
| Toowoomba Canary-grass | *Phalaris aquatica* | Poaceae | | | | * |
| Lesser Canary-grass | *Phalaris minor* | Poaceae | | | | * |
| Common Reed | *Phragmites australis* | Poaceae | | | | |
| Rice Millet | *Piptatherum miliaceum* | Poaceae | | | | * |
| Common Tussock-grass | *Poa labillardierei* | Poaceae | | | | |
| Coast Tussock-grass | *Poa poiformis* | Poaceae | | | | |
| Coast Tussock-grass | *Poa poiformis* var. *poiformis* | Poaceae | | | | |
| Annual Beard-grass | *Polypogon monspeliensis* | Poaceae | | | | * |
| Australian Saltmarsh-grass | *Puccinellia stricta* | Poaceae | | | | |
| Plains Saltmarsh-grass | *Puccinellia stricta* var. *perlaxa* | Poaceae | | | | |
| Australian Saltmarsh-grass | *Puccinellia stricta* var. *stricta* | Poaceae | | | | |
| Rat-tail Grass | *Sporobolus africanus* | Poaceae | | | | * |
| Buffalo Grass | *Stenotaphrum secundatum* | Poaceae | | | | * |
| Sea Wheat-grass | *Thinopyrum junceiforme* | Poaceae | | | | * |
| Squirrel-tail Fescue | *Vulpia bromoides* | Poaceae | | | | * |
| Spiny Emex | *Emex australis* | Polygonaceae | | | | * |
| Tangled Lignum | *Muehlenbeckia florulenta* | Polygonaceae | | | | |
| Slender Knotweed | *Persicaria decipiens* | Polygonaceae | | | | |
| Pale Knotweed | *Persicaria lapathifolia* | Polygonaceae | | | | |
| Hogweed | *Polygonum aviculare s.s.* | Polygonaceae | | | | * |
| Mud Dock | *Rumex bidens* | Polygonaceae | | | | |
| Clustered Dock | *Rumex conglomeratus* | Polygonaceae | | | | * |
| Curled Dock | *Rumex crispus* | Polygonaceae | | | | * |
| Fiddle Dock | *Rumex pulcher* subsp. *pulcher* | Polygonaceae | | | | * |
| Dock (naturalised) | *Rumex* spp. (naturalised) | Polygonaceae | | | | * |
| White Purslane | *Neopaxia australasica* | Portulacaceae | | | | |
| Blunt Pondweed | *Potamogeton ochreatus* | Potamogetonaceae | | | | |
| Fennel Pondweed | *Potamogeton pectinatus* | Potamogetonaceae | | | | |
| Pimpernel | *Anagallis arvensis* | Primulaceae | | | | * |
| Creeping Brookweed | *Samolus repens* | Primulaceae | | | | |
| Water Fennel | *Batrachium trichophyllum* | Ranunculaceae | | | | * |

| Common Name | Scientific Name | Family | FFG | EPBC | VROTS | Origin |
|---|---|---|---|---|---|---|
| Small-leaved Clematis | *Clematis microphylla* | Ranunculaceae | | | | |
| Small River Buttercup | *Ranunculus amphitrichus* | Ranunculaceae | | | | |
| Italian Buckthorn | *Rhamnus alaternus* | Rhamnaceae | | | | * |
| Bidgee-widgee | *Acaena novae-zelandiae* | Rosaceae | | | | |
| Large-leaf Cotoneaster | *Cotoneaster glaucophyllus* var. *serotinus* | Rosaceae | | | | * |
| Sweet Briar | *Rosa rubiginosa* | Rosaceae | | | | * |
| Blackberry | *Rubus fruticosus* spp. agg. | Rosaceae | | | | * |
| Common Woodruff | *Asperula conferta* | Rubiaceae | | | | |
| Mirror Bush | *Coprosma repens* | Rubiaceae | | | | * |
| Cleavers | *Galium aparine* | Rubiaceae | | | | * |
| Field Madder | *Sherardia arvensis* | Rubiaceae | | | | * |
| Sea Tassel | *Ruppia maritima s.l.* | Ruppiaceae | | | | |
| Grey Sallow | *Salix cinerea* | Salicaceae | | | | * |
| Willow | *Salix* spp. | Salicaceae | | | | * |
| Creeping Monkey-flower | *Mimulus repens* | Scrophulariaceae | | | | |
| Slender Speedwell | *Veronica gracilis* | Scrophulariaceae | | | | |
| African Box-thorn | *Lycium ferocissimum* | Solanaceae | | | | * |
| Sticky Ground-cherry | *Physalis viscosa* | Solanaceae | | | | * |
| Kangaroo Apple | *Solanum aviculare* | Solanaceae | | | | |
| Large Kangaroo Apple | *Solanum laciniatum* | Solanaceae | | | | |
| Apple of Sodom | *Solanum linnaeanum* | Solanaceae | | | | * |
| Thyme Rice-flower | *Pimelea serpyllifolia* subsp. *serpyllifolia* | Thymelaeaceae | | | | |
| Narrow-leaf Cumbungi | *Typha domingensis* | Typhaceae | | | | |
| Broad-leaf Cumbungi | *Typha orientalis* | Typhaceae | | | | |
| Bulrush | *Typha* spp. | Typhaceae | | | | |
| Small Nettle | *Urtica urens* | Urticaceae | | | | * |
| Grey Mangrove | *Avicennia marina* subsp. *australasica* | Verbenaceae | | | r | |
| Small-fruit Water-mat | *Lepilaena bilocularis* | Zannichelliaceae | | | | |
| Long-fruit Water-mat | *Lepilaena cylindrocarpa* | Zannichelliaceae | | | | |
| Slender Water-mat | *Lepilaena preissii* | Zannichelliaceae | | | | |
| Coast Twin-leaf | *Zygophyllum billardierei* | Zygophyllaceae | | | r | |

f – listed under Schedule 2 of the Flora and Fauna Guarantee Act 1988 (FFG Act)
E- listed as endangered under the Environment Protection and Biodiversity Conservation Act 1999 (EPBC Act)
V - listed as vulnerable under the Environment Protection and Biodiversity Conservation Act 1999 (EPBC Act)
c - listed as critically endangered within the Victorian Rare or Threatened Species list (VROTS)
e- listed as endangered upon the Victorian Rare or Threatened Species list (VROTS)
v- listed as vulnerable uponthe Victorian Rare or Threatened Species list (VROTS)
r- listed as rare upon the Victorian Rare or Threatened Species list (VROTS)
n-nominated to be placed upon the Victorian Rare or Threatened Species list (VROTS)
*- introduced species

# Appendix C Atlas of Victorian Wildlife Search List for the Lake Connewarre Complex

(Search conducted May 2007)

| Common Name | Scientific Name | Family Name | Freq | NumSite | FFG | EPBC | VROTS | Origin |
|---|---|---|---|---|---|---|---|---|
| **Mammals** | | | | | | | | |
| Red Fox | *Canis vulpes* | Canidae | 0.60% | 3 | | | | * |
| European Rabbit | *Oryctolagus cuniculus* | Leporidae | 0.20% | 1 | | | | * |
| Water Rat | *Hydromys chrysogaster* | Muridae | 0.20% | 1 | | | | |
| House Mouse | *Mus musculus* | Muridae | 0.20% | 1 | | | | * |
| Swamp Rat | *Rattus lutreolus* | Muridae | 0.20% | 1 | | | | |
| Australian Fur Seal | *Arctocephalus pusillus* | Otariidae | 0.20% | 1 | | | | |
| Koala | *Phascolarctos cinereus* | Phascolarctidae | 0.20% | 1 | | | | |
| Leopard Seal | *Hydrurga leptonyx* | Phocidae | 0.20% | 1 | | | | |
| Common Ringtail Possum | *Pseudocheirus peregrinus* | Pseudocheiridae | 0.40% | 2 | | | | |
| Short-beaked Echidna | *Tachyglossus aculeatus* | Tachyglossidae | 0.40% | 2 | | | | |
| **Birds** | | | | | | | | |
| Brown Goshawk | *Accipiter fasciatus* | Accipitridae | 1.41% | 7 | | | | |
| Grey Goshawk | *Accipiter novaehollandiae* | Accipitridae | 0.20% | 1 | | | v | |
| Wedge-tailed Eagle | *Aquila audax* | Accipitridae | 0.20% | 1 | | | | |
| Swamp Harrier | *Circus approximans* | Accipitridae | 16.12% | 80 | | | | |
| Black-shouldered Kite | *Elanus axillaris* | Accipitridae | 5.84% | 29 | | | | |
| White-bellied Sea-Eagle | *Haliaeetus leucogaster* | Accipitridae | 1.41% | 7 | f | | v | |
| Whistling Kite | *Haliastur sphenurus* | Accipitridae | 5.84% | 29 | | | | |
| Little Eagle | *Hieraaetus morphnoides* | Accipitridae | 0.60% | 3 | | | | |
| Skylark | *Alauda arvensis* | Alaudidae | 9.87% | 49 | | | | * |
| Singing Bushlark | *Mirafra javanica* | Alaudidae | 0.60% | 3 | | | | |
| Chestnut Teal | *Anas castanea* | Anatidae | 12.09% | 60 | | | | |
| Grey Teal | *Anas gracilis* | Anatidae | 10.28% | 51 | | | | |
| Mallard | *Anas platyrhynchos* | Anatidae | 0.20% | 1 | | | | * |

| Common Name | Scientific Name | Family Name | Freq | NumSite | FFG | EPBC | VROTS | Origin |
|---|---|---|---|---|---|---|---|---|
| Australasian Shoveler | *Anas rhynchotis* | Anatidae | 8.26% | 41 | | | v | |
| Pacific Black Duck | *Anas superciliosa* | Anatidae | 20.16% | 100 | | | | |
| Hardhead | *Aythya australis* | Anatidae | 5.04% | 25 | | | v | |
| Musk Duck | *Biziura lobata* | Anatidae | 4.23% | 21 | | | v | |
| Cape Barren Goose | *Cereopsis novaehollandiae* | Anatidae | 0.40% | 2 | | | n | |
| Australian Wood Duck | *Chenonetta jubata* | Anatidae | 0.20% | 1 | | | | |
| Black Swan | *Cygnus atratus* | Anatidae | 30.04% | 149 | | | | |
| Pink-eared Duck | *Malacorhynchus membranaceus* | Anatidae | 0.80% | 4 | | | | |
| Blue-billed Duck | *Oxyura australis* | Anatidae | 0.60% | 3 | f | | e | |
| Freckled Duck | *Stictonetta naevosa* | Anatidae | 0.80% | 4 | f | | e | |
| Australian Shelduck | *Tadorna tadornoides* | Anatidae | 16.33% | 81 | | | | |
| Darter | *Anhinga melanogaster* | Anhingidae | 0.60% | 3 | | | | |
| Magpie Goose | *Anseranas semipalmata* | Anseranatidae | 3.42% | 17 | | | v | |
| Great Egret | *Ardea alba* | Ardeidae | 15.72% | 78 | f | | v | |
| Cattle Egret | *Ardea ibis* | Ardeidae | 0.80% | 4 | | | | |
| Intermediate Egret | *Ardea intermedia* | Ardeidae | 0.60% | 3 | f | | c | |
| White-necked Heron | *Ardea pacifica* | Ardeidae | 1.81% | 9 | | | | |
| Australasian Bittern | *Botaurus poiciloptilus* | Ardeidae | 4.63% | 23 | f | | e | |
| Little Egret | *Egretta garzetta* | Ardeidae | 3.22% | 16 | f | | e | |
| White-faced Heron | *Egretta novaehollandiae* | Ardeidae | 23.18% | 115 | | | | |
| Little Bittern | *Ixobrychus minutus* | Ardeidae | 0.20% | 1 | f | | e | |
| Masked Woodswallow | *Artamus personatus* | Artamidae | 0.20% | 1 | | | | |
| White-browed Woodswallow | *Artamus superciliosus* | Artamidae | 0.40% | 2 | | | | |
| Grey Butcherbird | *Cracticus torquatus* | Artamidae | 7.86% | 39 | | | | |
| Australian Magpie | *Gymnorhina tibicen* | Artamidae | 23.99% | 119 | | | | |
| Pied Currawong | *Strepera graculina* | Artamidae | 0.40% | 2 | | | | |
| Grey Currawong | *Strepera versicolor* | Artamidae | 0.40% | 2 | | | | |
| Sulphur-crested Cockatoo | *Cacatua galerita* | Cacatuidae | 2.01% | 10 | | | | |
| Galah | *Cacatua roseicapilla* | Cacatuidae | 4.83% | 24 | | | | |
| Long-billed Corella | *Cacatua tenuirostris* | Cacatuidae | 0.20% | 1 | | | | |
| Gang-gang Cockatoo | *Callocephalon fimbriatum* | Cacatuidae | 0.40% | 2 | | | | |

| **Common Name** | **Scientific Name** | **Family Name** | **Freq** | **NumSite** | **FFG** | **EPBC** | **VROTS** | **Origin** |
|---|---|---|---|---|---|---|---|---|
| Yellow-tailed Black-Cockatoo | *Calyptorhynchus funereus* | Cacatuidae | 3.83% | 19 | | | | |
| Black-faced Cuckoo-shrike | *Coracina novaehollandiae* | Campephagidae | 2.41% | 12 | | | | |
| Double-banded Plover | *Charadrius bicinctus* | Charadriidae | 2.41% | 12 | | | | |
| Little Ringed Plover | *Charadrius dubius* | Charadriidae | 0.20% | 1 | | | | |
| Red-capped Plover | *Charadrius ruficapillus* | Charadriidae | 6.45% | 32 | | | | |
| Black-fronted Dotterel | *Elseyornis melanops* | Charadriidae | 3.42% | 17 | | | | |
| Red-kneed Dotterel | *Erythrogonys cinctus* | Charadriidae | 5.04% | 25 | | | | |
| Pacific Golden Plover | *Pluvialis fulva* | Charadriidae | 0.60% | 3 | | | n | |
| Hooded Plover | *Thinornis rubricollis* | Charadriidae | 2.82% | 14 | f | | v | |
| Masked Lapwing | *Vanellus miles* | Charadriidae | 29.43% | 146 | | | | |
| Banded Lapwing | *Vanellus tricolor* | Charadriidae | 0.40% | 2 | | | | |
| Rock Dove | *Columba livia* | Columbidae | 0.60% | 3 | | | | * |
| Diamond Dove | *Geopelia cuneata* | Columbidae | 0.40% | 2 | f | | n | |
| Spotted Turtle-Dove | *Streptopelia chinensis* | Columbidae | 14.91% | 74 | | | | * |
| Australian Raven | *Corvus coronoides* | Corvidae | 0.80% | 4 | | | | |
| Little Raven | *Corvus mellori* | Corvidae | 15.72% | 78 | | | | |
| Fan-tailed Cuckoo | *Cacomantis flabelliformis* | Cuculidae | 1% | 5 | | | | |
| Horsfield's Bronze-Cuckoo | *Chrysococcyx basalis* | Cuculidae | 2.21% | 11 | | | | |
| Shining Bronze-Cuckoo | *Chrysococcyx lucidus* | Cuculidae | 0.60% | 3 | | | | |
| Pallid Cuckoo | *Cuculus pallidus* | Cuculidae | 0.80% | 4 | | | | |
| Mistletoebird | *Dicaeum hirundinaceum* | Dicaeidae | 0.40% | 2 | | | | |
| Magpie-lark | *Grallina cyanoleuca* | Dicruridae | 15.52% | 77 | | | | |
| Restless Flycatcher | *Myiagra inquieta* | Dicruridae | 0.20% | 1 | | | | |
| Leaden Flycatcher | *Myiagra rubecula* | Dicruridae | 0.20% | 1 | | | | |
| Grey Fantail | *Rhipidura fuliginosa* | Dicruridae | 4.03% | 20 | | | | |
| Willie Wagtail | *Rhipidura leucophrys* | Dicruridae | 17.94% | 89 | | | | |
| Brown Falcon | *Falco berigora* | Falconidae | 4.63% | 23 | | | | |
| Nankeen Kestrel | *Falco cenchroides* | Falconidae | 2.01% | 10 | | | | |
| Australian Hobby | *Falco longipennis* | Falconidae | 2.01% | 10 | | | | |
| Peregrine Falcon | *Falco peregrinus* | Falconidae | 0.20% | 1 | | | | |
| Black Falcon | *Falco subniger* | Falconidae | 0.40% | 2 | | | v | |

| Common Name | Scientific Name | Family Name | Freq | NumSite | FFG | EPBC | VROTS | Origin |
|---|---|---|---|---|---|---|---|---|
| European Goldfinch | *Carduelis carduelis* | Fringillidae | 11.49% | 57 | | | | * |
| European Greenfinch | *Carduelis chloris* | Fringillidae | 1.81% | 9 | | | | * |
| Brolga | *Grus rubicunda* | Gruidae | 0.80% | 4 | f | | v | |
| Sooty Oystercatcher | *Haematopus fuliginosus* | Haematopodidae | 0.20% | 1 | | | n | |
| Pied Oystercatcher | *Haematopus longirostris* | Haematopodidae | 1.20% | 6 | | | | |
| Laughing Kookaburra | *Dacelo novaeguineae* | Halcyonidae | 0.20% | 1 | | | | |
| Sacred Kingfisher | *Todiramphus sanctus* | Halcyonidae | 0.20% | 1 | | | | |
| Fairy Martin | *Hirundo ariel* | Hirundinidae | 1.61% | 8 | | | | |
| Welcome Swallow | *Hirundo neoxena* | Hirundinidae | 21.57% | 107 | | | | |
| Tree Martin | *Hirundo nigricans* | Hirundinidae | 1% | 5 | | | | |
| White-faced Storm-Petrel | *Pelagodroma marina* | Hydrobatidae | 0.20% | 1 | | | n | |
| Whiskered Tern | *Chlidonias hybridus* | Laridae | 6.25% | 31 | | | n | |
| White-winged Black Tern | *Chlidonias leucopterus* | Laridae | 1.41% | 7 | | | n | |
| Silver Gull | *Larus novaehollandiae* | Laridae | 18.95% | 94 | | | | |
| Pacific Gull | *Larus pacificus* | Laridae | 9.07% | 45 | | | n | |
| Little Tern | *Sterna albifrons* | Laridae | 1% | 5 | f | | v | |
| Crested Tern | *Sterna bergii* | Laridae | 4.63% | 23 | | | | |
| Caspian Tern | *Sterna caspia* | Laridae | 7.45% | 37 | f | | n | |
| Fairy Tern | *Sterna nereis* | Laridae | 1% | 5 | f | | e | |
| Gull-billed Tern | *Sterna nilotica* | Laridae | 2.21% | 11 | f | | e | |
| White-fronted Tern | *Sterna striata* | Laridae | 0.40% | 2 | | | n | |
| Superb Fairy-wren | *Malurus cyaneus* | Maluridae | 17.33% | 86 | | | | |
| Southern Emu-wren | *Stipiturus malachurus* | Maluridae | 0.20% | 1 | | | | |
| Spiny-cheeked Honeyeater | *Acanthagenys rufogularis* | Meliphagidae | 5.04% | 25 | | | | |
| Eastern Spinebill | *Acanthorhynchus tenuirostris* | Meliphagidae | 2.62% | 13 | | | | |
| Red Wattlebird | *Anthochaera carunculata* | Meliphagidae | 15.32% | 76 | | | | |
| Little Wattlebird | *Anthochaera chrysoptera* | Meliphagidae | 0.60% | 3 | | | | |
| White-fronted Chat | *Epthianura albifrons* | Meliphagidae | 13.91% | 69 | | | | |
| Yellow-faced Honeyeater | *Lichenostomus chrysops* | Meliphagidae | 0.80% | 4 | | | | |
| White-plumed Honeyeater | *Lichenostomus penicillatus* | Meliphagidae | 5.24% | 26 | | | | |
| Singing Honeyeater | *Lichenostomus virescens* | Meliphagidae | 1.81% | 9 | | | | |

| Common Name | Scientific Name | Family Name | Freq | NumSite | FFG | EPBC | VROTS | Origin |
|---|---|---|---|---|---|---|---|---|
| Noisy Miner | *Manorina melanocephala* | Meliphagidae | 2.62% | 13 | | | | |
| White-naped Honeyeater | *Melithreptus lunatus* | Meliphagidae | 0.20% | 1 | | | | |
| New Holland Honeyeater | *Phylidonyris novaehollandiae* | Meliphagidae | 11.69% | 58 | | | | |
| Richard's Pipit | *Anthus novaeseelandiae* | Motacillidae | 1.41% | 7 | | | | |
| Common Blackbird | *Turdus merula* | Muscicapidae | 15.32% | 76 | | | | * |
| Grey Shrike-thrush | *Colluricincla harmonica* | Pachycephalidae | 0.20% | 1 | | | | |
| Golden Whistler | *Pachycephala pectoralis* | Pachycephalidae | 0.20% | 1 | | | | |
| Yellow-rumped Thornbill | *Acanthiza chrysorrhoa* | Pardalotidae | 6.65% | 33 | | | | |
| Striated Thornbill | *Acanthiza lineata* | Pardalotidae | 0.20% | 1 | | | | |
| Yellow Thornbill | *Acanthiza nana* | Pardalotidae | 0.20% | 1 | | | | |
| Brown Thornbill | *Acanthiza pusilla* | Pardalotidae | 5.64% | 28 | | | | |
| Striated Fieldwren | *Calamanthus fuliginosus* | Pardalotidae | 5.84% | 29 | | | | |
| Spotted Pardalote | *Pardalotus punctatus* | Pardalotidae | 0.80% | 4 | | | | |
| Striated Pardalote | *Pardalotus striatus* | Pardalotidae | 0.40% | 2 | | | | |
| White-browed Scrubwren | *Sericornis frontalis* | Pardalotidae | 1.61% | 8 | | | | |
| Red-browed Finch | *Neochmia temporalis* | Passeridae | 0.20% | 1 | | | | |
| House Sparrow | *Passer domesticus* | Passeridae | 10.28% | 51 | | | | * |
| Eurasian Tree Sparrow | *Passer montanus* | Passeridae | 0.20% | 1 | | | | * |
| Beautiful Firetail | *Stagonopleura bella* | Passeridae | 0.20% | 1 | | | | |
| Australian Pelican | *Pelecanus conspicillatus* | Pelecanidae | 18.14% | 90 | | | | |
| Flame Robin | *Petroica phoenicea* | Petroicidae | 0.80% | 4 | | | | |
| Pink Robin | *Petroica rodinogaster* | Petroicidae | 0.40% | 2 | | | | |
| Great Cormorant | *Phalacrocorax carbo* | Phalacrocoracidae | 12.90% | 64 | | | | |
| Little Pied Cormorant | *Phalacrocorax melanoleucos* | Phalacrocoracidae | 15.92% | 79 | | | | |
| Little Black Cormorant | *Phalacrocorax sulcirostris* | Phalacrocoracidae | 8.46% | 42 | | | | |
| Pied Cormorant | *Phalacrocorax varius* | Phalacrocoracidae | 7.05% | 35 | | | n | |
| Stubble Quail | *Coturnix pectoralis* | Phasianidae | 0.80% | 4 | | | | |
| Brown Quail | *Coturnix ypsilophora* | Phasianidae | 0.20% | 1 | | | n | |
| Great Crested Grebe | *Podiceps cristatus* | Podicipedidae | 2.21% | 11 | | | | |
| Hoary-headed Grebe | *Poliocephalus poliocephalus* | Podicipedidae | 9.27% | 46 | | | | |
| Australasian Grebe | *Tachybaptus novaehollandiae* | Podicipedidae | 3.42% | 17 | | | | |

| Common Name | Scientific Name | Family Name | Freq | NumSite | FFG | EPBC | VROTS | Origin |
|---|---|---|---|---|---|---|---|---|
| Cape Petrel | *Daption capense* | Procellariidae | 0.20% | 1 | | | | |
| Slender-billed Prion | *Pachyptila belcheri* | Procellariidae | 0.60% | 3 | | | | |
| Fairy Prion | *Pachyptila turtur* | Procellariidae | 1.81% | 9 | | V | v | |
| Common Diving-Petrel | *Pelecanoides urinatrix* | Procellariidae | 1% | 5 | | | n | |
| Fluttering Shearwater | *Puffinus gavia* | Procellariidae | 1.61% | 8 | | | | |
| Short-tailed Shearwater | *Puffinus tenuirostris* | Procellariidae | 2.41% | 12 | | | | |
| Musk Lorikeet | *Glossopsitta concinna* | Psittacidae | 0.80% | 4 | | | | |
| Purple-crowned Lorikeet | *Glossopsitta porphyrocephala* | Psittacidae | 0.40% | 2 | | | | |
| Orange-bellied Parrot | *Neophema chrysogaster* | Psittacidae | 13.70% | 68 | f | E | c | |
| Blue-winged Parrot | *Neophema chrysostoma* | Psittacidae | 4.23% | 21 | | | | |
| Crimson Rosella | *Platycercus elegans* | Psittacidae | 2.01% | 10 | | | | |
| Eastern Rosella | *Platycercus eximius* | Psittacidae | 6.65% | 33 | | | | |
| Red-rumped Parrot | *Psephotus haematonotus* | Psittacidae | 2.01% | 10 | | | | |
| Rainbow Lorikeet | *Trichoglossus haematodus* | Psittacidae | 0.20% | 1 | | | | |
| Eurasian Coot | *Fulica atra* | Rallidae | 7.45% | 37 | | | | |
| Dusky Moorhen | *Gallinula tenebrosa* | Rallidae | 2.01% | 10 | | | | |
| Black-tailed Native-hen | *Gallinula ventralis* | Rallidae | 0.60% | 3 | | | | |
| Buff-banded Rail | *Gallirallus philippensis* | Rallidae | 0.20% | 1 | | | | |
| Purple Swamphen | *Porphyrio porphyrio* | Rallidae | 12.50% | 62 | | | | |
| Australian Spotted Crake | *Porzana fluminea* | Rallidae | 3.42% | 17 | | | | |
| Baillon's Crake | *Porzana pusilla* | Rallidae | 2.21% | 11 | f | | v | |
| Spotless Crake | *Porzana tabuensis* | Rallidae | 0.40% | 2 | | | | |
| Banded Stilt | *Cladorhynchus leucocephalus* | Recurvirostridae | 0.60% | 3 | | | | |
| Black-winged Stilt | *Himantopus himantopus* | Recurvirostridae | 8.26% | 41 | | | | |
| Red-necked Avocet | *Recurvirostra novaehollandiae* | Recurvirostridae | 2.01% | 10 | | | | |
| Painted Snipe | *Rostratula benghalensis* | Rostratulidae | 0.40% | 2 | f | V | c | |
| Common Sandpiper | *Actitis hypoleucos* | Scolopacidae | 1.41% | 7 | | | v | |
| Sharp-tailed Sandpiper | *Calidris acuminata* | Scolopacidae | 8.26% | 41 | | | | |
| Baird's Sandpiper | *Calidris bairdii* | Scolopacidae | 0.20% | 1 | | | | |
| Red Knot | *Calidris canutus* | Scolopacidae | 1.61% | 8 | | | n | |
| Curlew Sandpiper | *Calidris ferruginea* | Scolopacidae | 6.65% | 33 | | | | |

| Common Name | Scientific Name | Family Name | Freq | NumSite | FFG | EPBC | VROTS | Origin |
|---|---|---|---|---|---|---|---|---|
| Pectoral Sandpiper | *Calidris melanotos* | Scolopacidae | 1.81% | 9 | | | n | |
| Red-necked Stint | *Calidris ruficollis* | Scolopacidae | 8.66% | 43 | | | | |
| Long-toed Stint | *Calidris subminuta* | Scolopacidae | 0.60% | 3 | | | | |
| Great Knot | *Calidris tenuirostris* | Scolopacidae | 0.80% | 4 | f | | e | |
| Latham's Snipe | *Gallinago hardwickii* | Scolopacidae | 2.21% | 11 | | | n | |
| Broad-billed Sandpiper | *Limicola falcinellus* | Scolopacidae | 0.20% | 1 | | | | |
| Bar-tailed Godwit | *Limosa lapponica* | Scolopacidae | 2.01% | 10 | | | | |
| Black-tailed Godwit | *Limosa limosa* | Scolopacidae | 1.20% | 6 | | | v | |
| Eastern Curlew | *Numenius madagascariensis* | Scolopacidae | 5.04% | 25 | | | n | |
| Red-necked Phalarope | *Phalaropus lobatus* | Scolopacidae | 0.20% | 1 | | | | |
| Ruff | *Philomachus pugnax* | Scolopacidae | 0.20% | 1 | | | | |
| Lesser Yellowlegs | *Tringa flavipes* | Scolopacidae | 0.20% | 1 | | | | |
| Wood Sandpiper | *Tringa glareola* | Scolopacidae | 0.40% | 2 | | | v | |
| Common Greenshank | *Tringa nebularia* | Scolopacidae | 13.10% | 65 | | | | |
| Marsh Sandpiper | *Tringa stagnatilis* | Scolopacidae | 2.41% | 12 | | | | |
| Terek Sandpiper | *Xenus cinereus* | Scolopacidae | 0.20% | 1 | f | | e | |
| Little Penguin | *Eudyptula minor* | Spheniscidae | 3.42% | 17 | | | | |
| Common Myna | *Acridotheres tristis* | Sturnidae | 7.86% | 39 | | | | * |
| Common Starling | *Sturnus vulgaris* | Sturnidae | 14.51% | 72 | | | | * |
| Australasian Gannet | *Morus serrator* | Sulidae | 1.41% | 7 | | | | |
| Clamorous Reed Warbler | *Acrocephalus stentoreus* | Sylviidae | 5.84% | 29 | | | | |
| Brown Songlark | *Cincloramphus cruralis* | Sylviidae | 0.40% | 2 | | | | |
| Golden-headed Cisticola | *Cisticola exilis* | Sylviidae | 12.70% | 63 | | | | |
| Little Grassbird | *Megalurus gramineus* | Sylviidae | 11.08% | 55 | | | | |
| Yellow-billed Spoonbill | *Platalea flavipes* | Threskiornithidae | 8.26% | 41 | | | | |
| Royal Spoonbill | *Platalea regia* | Threskiornithidae | 16.73% | 83 | | | v | |
| Glossy Ibis | *Plegadis falcinellus* | Threskiornithidae | 3.62% | 18 | | | n | |
| Australian White Ibis | *Threskiornis molucca* | Threskiornithidae | 23.58% | 117 | | | | |
| Straw-necked Ibis | *Threskiornis spinicollis* | Threskiornithidae | 14.91% | 74 | | | | |
| Barn Owl | *Tyto alba* | Tytonidae | 0.20% | 1 | | | | |
| Silvereye | *Zosterops lateralis* | Zosteropidae | 6.45% | 32 | | | | |

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|---|---|---|---|---|---|---|---|---|
| **Reptiles** | | | | | | | | |
| Lowland Copperhead | *Austrelaps superbus* | Elapidae | 0.20% | 1 | | | | |
| Large Striped Skink | *Ctenotus robustus* | Scincidae | 0.20% | 1 | | | | |
| **Frogs** | | | | | | | | |
| Southern Brown Tree Frog | *Litoria ewingii* | Hylidae | 0.40% | 2 | | | | |
| Growling Grass Frog | *Litoria raniformis* | Hylidae | 0.40% | 2 | f | V | e | |
| Common Froglet | *Crinia signifera* | Myobatrachidae | 1% | 5 | | | | |
| **Fish** | | | | | | | | |
| Small-mouthed Hardyhead | *Atherinosoma microstoma* | Atherinidae | 0.60% | 3 | | | | |
| Tupong | *Pseudaphritis urvillii* | Bovichthyidae | 0.80% | 4 | | | | |
| Sandy Sprat | *Hyperlophus vittatus* | Clupeidae | 0.40% | 2 | | | | |
| Goldfish | *Carassius auratus* | Cyprinidae | 0.40% | 2 | | | | * |
| Carp | *Cyprinus carpio* | Cyprinidae | 0.60% | 3 | | | | * |
| Tench | *Tinca tinca* | Cyprinidae | 0.40% | 2 | | | | * |
| Flatheaded Gudgeon | *Philypnodon grandiceps* | Eleotrididae | 0.80% | 4 | | | | |
| Broadfin Galaxias | *Galaxias brevipinnis* | Galaxiidae | 0.60% | 3 | | | | |
| Common Galaxias | *Galaxias maculatus* | Galaxiidae | 4.03% | 20 | | | | |
| Spotted Galaxias | *Galaxias truttaceus* | Galaxiidae | 1.61% | 8 | | | | |
| Bridled Goby | *Arenigobius bifrenatus* | Gobiidae | 0.20% | 1 | | | | |
| Lagoon Goby | *Tasmanogobius lasti* | Gobiidae | 0.40% | 2 | | | | |
| Yelloweye Mullet | *Aldrichetta forsteri* | Mugilidae | 0.80% | 4 | | | | |
| Redfin | *Perca fluviatilis* | Percidae | 0.20% | 1 | | | | * |
| Pouched Lamprey | *Geotria australis* | Petromyzontidae | 0.20% | 1 | | | | |
| Mosquitofish | *Gambusia holbrooki* | Poecilidae | 0.60% | 3 | | | | * |
| Australian Grayling | *Prototroctes maraena* | Prototroctidae | 1% | 5 | f | V | v | |
| Australian Smelt | *Retropinna semoni* | Retropinnidae | 3.02% | 15 | | | | |
| Shortfin Eel | *Anguilla australis* | Undetermined | 2.21% | 11 | | | | |
| Sand Trevally | *Pseudocaranx wrighti* | Undetermined | 0.20% | 1 | | | | |

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|---|---|---|---|---|---|---|---|---|
| **Invertebrates** | | | | | | | | |
| Altona Skipper | *Hesperilla flavescens flavescens* | Hesperiidae | 0.40% | 2 | | | | |
| Common Freshwater Shrimp | *Paratya australiensis* | Und. Invertebrate | 0.20% | 1 | | | | |

f – listed under Schedule 2 of the Flora and Fauna Guarantee Act 1988 (FFG Act)
E- listed as endangered under the Environment Protection and Biodiversity Conservation Act 1999 (EPBC Act)
V - listed as vulnerable under the Environment Protection and Biodiversity Conservation Act 1999 (EPBC Act)
c - listed as critically endangered within the Victorian Rare or Threatened Species list (VROTS)
e- listed as endangered upon the Victorian Rare or Threatened Species list (VROTS)
v- listed as vulnerable upon the Victorian Rare or Threatened Species list (VROTS)
r- listed as rare upon the Victorian Rare or Threatened Species list (VROTS)
n-nominated to be placed upon the Victorian Rare or Threatened Species list (VROTS)
*- introduced species