



**IAH-AIG Victoria**



**2013 field excursion**

**23<sup>rd</sup> November 2013**

**Hydrogeology and geomorphology of the Lake Connewarre Complex**

**Excursion Notes**



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**The material in this document has been compiled from various key sources of information, notably:**

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Barwon Water [www.barwonwater.vic.gov.au/](http://www.barwonwater.vic.gov.au/)

profile.id [profile.id.com.au/geelong/population-estimate](http://profile.id.com.au/geelong/population-estimate)

Department of Environment [www.environment.gov.au/topics/water/water-our-environment/wetlands/ramsar-convention-wetlands](http://www.environment.gov.au/topics/water/water-our-environment/wetlands/ramsar-convention-wetlands)

Friends of The Bluff [barwonbluff.com.au/the-bluff/barwon-bluff/](http://barwonbluff.com.au/the-bluff/barwon-bluff/)

## Brief summary

- This excursion travels to the lower Barwon River, wetlands and estuary which form part of the [Port Phillip Bay \(Western Shoreline\) and Bellarine Peninsula Ramsar Site](#) (listed 15<sup>th</sup> December 1982). The Ramsar site includes examples of saltmarshes, estuarine wetlands, and freshwater wetlands that support more than 20,000 waterbirds, including migratory waders, Black Swans, ducks, ibis and cormorants.
- The excursion mainly covers the [Lake Connewarre State Game Reserve](#) in which 137 native plants and 135 bird species have been recorded.
- The ecological health of these high-value environmental assets depends on the hydrological interactions between the groundwater systems and the surface water systems (freshwater and marine).

The main issues are:

- **environmental history** of the wetlands that have resulted in a legacy of regulated river flows, environmental contamination, sedimentation, exploitation of the natural resources, salinisation, habitat loss and invasion by exotic species.
- **groundwater dependence of the ecosystem**, especially the relationship of the vegetation mosaic to the salinity of the groundwater and the management of surface water levels to maintain the health of the wetland ecology.
- **encroaching urbanisation**, especially the new developments of Armstrong Creek, which will develop 22,000 housing lots for 55,000 to 65,000 people over the next few years. The development will change the regional hydrology by hard-paving surfaces, building water storage ponds, installing household water tanks and using recycled waste water for garden irrigation.
- **rising sea levels**, predicted as a result of changing climates, which will alter the hydrological balance of the estuary and wetlands, especially through the migration of the saltwater-freshwater interface in the groundwater aquifers.
- **reduced river flows**, predicted as a result of a drying climate together with water diversions (dams), river regulation (barrages) and the increasing frequency of droughts. The reduced freshwater flows will create higher salinities in the estuarine lakes.
- **managing conflicting uses**, such as allowing a high-value conservation area to be used for hunting water birds, commercial and recreational fishing and recreational activities. It is expected that there will be an increasing demand by the 50,000+ new residents of the adjacent Armstrong Creek housing development for recreational access to the wetlands.



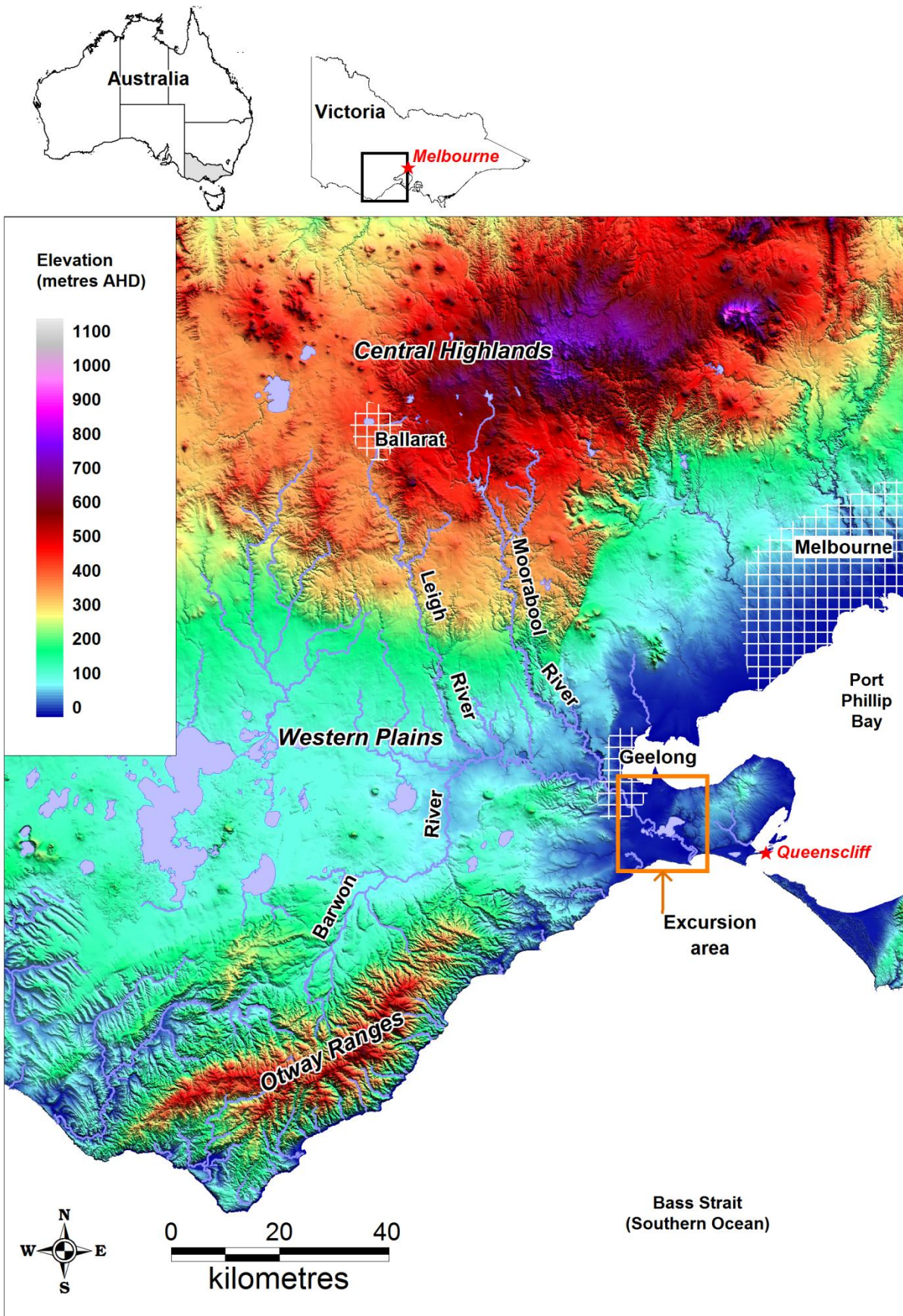


Figure 1. Regional overview of the lower Barwon River excursion area.

## Physiographic setting

The Barwon River has its headwaters in the Otway Ranges, along the south coast of Victoria. It is joined by two main rivers from the north: the Leigh River and the Moorabool River which drain the southern slopes of the Victorian Central Highlands (Great Dividing Range). The river is about 160 kilometres long and has a catchment of around 8,590 km<sup>2</sup>. It passes through the City of Geelong and then across the Bellarine Peninsula to enter the sea at Barwon Heads.

The wetlands and estuary associated with the lower reach of the river (i.e. the Ramsar Site) occupies low-lying land known as the Moolap Sunkland, a graben-like structure between the uplifted Bellarine High and the Barrabool Hills.

The Barwon, Leigh and Moorabool rivers are highly regulated and have a number of on-stream urban water supply dams, as well as diversions to and from other catchments.

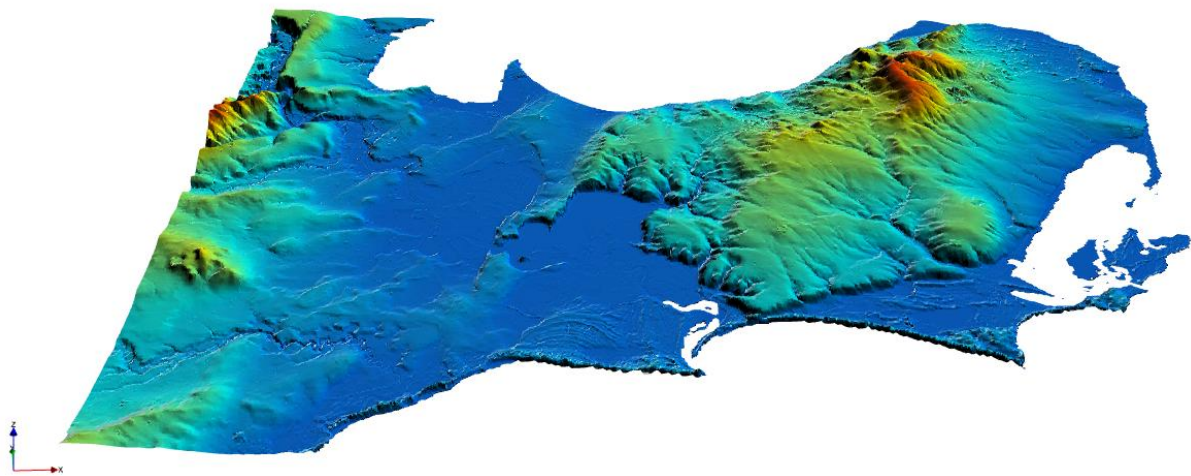
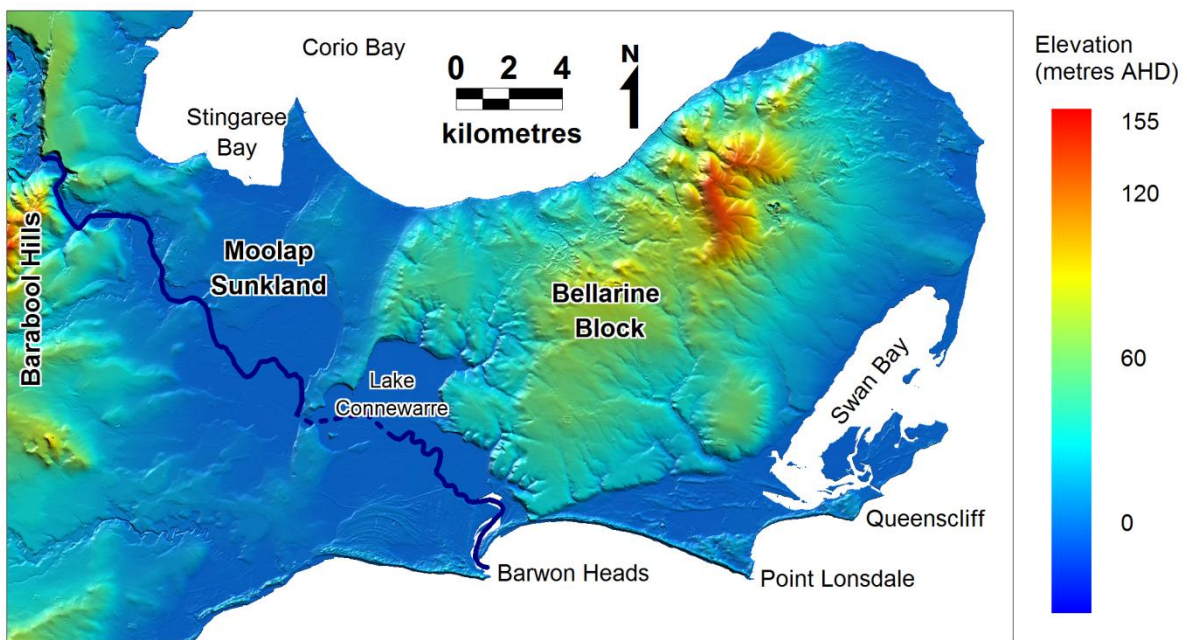
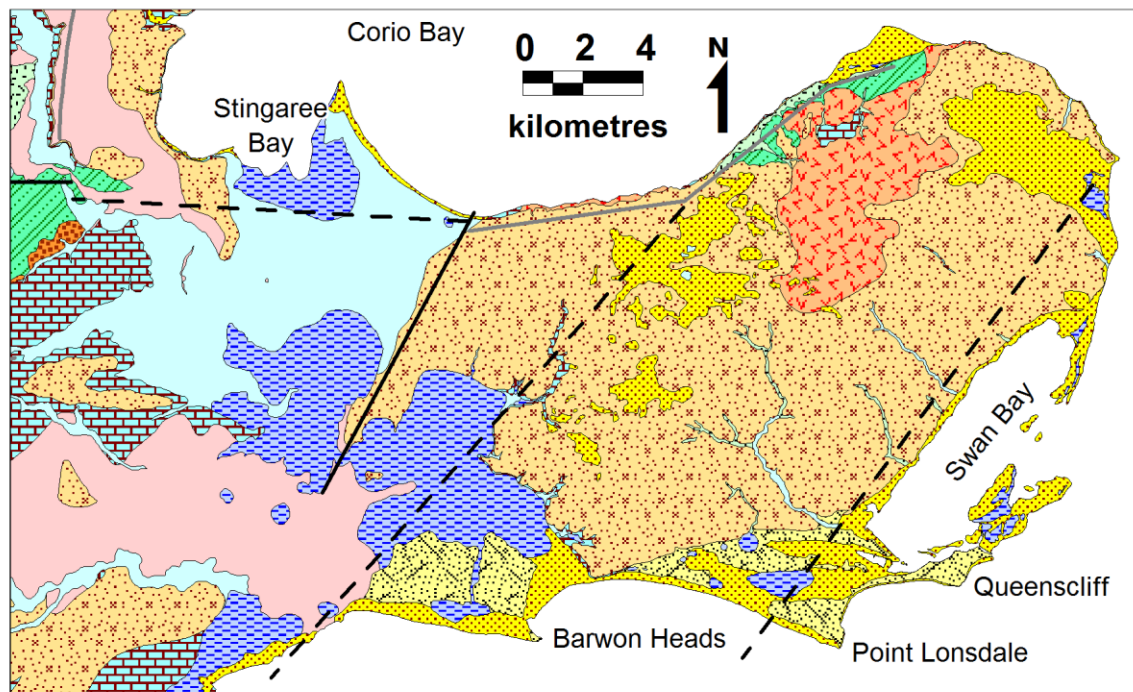


Figure 2. Physiography of the Bellarine Peninsula

The basement rocks of the Bellarine Peninsula are the Otway Group lithic sandstones and mudstones deposited in a terrestrial rift valley during the Cretaceous Period (65 Ma), formed when Australia was breaking away from Antarctica in the final split of Gondwana. These rocks occur in outcrop in the Barrabool Hills and Bellarine Block.

A series of terrestrial, volcanic and marine sediments were subsequently deposited as Australia moved north during the Palaeogene and opened up a seaway in the Neogene. A marine transgression and recession during the late Neogene (4Ma) left behind a thin (~5m) blanket of sand, which now covers much of the Bellarine Block.

Volcanic activity during the late Neogene and into the Quaternary resulted in basaltic lava flows that disrupted the pre-existing drainage. These lava flows and resulting basalt rocks of the Newer Volcanic Group have shaped the route of the modern-day Barwon River.



**Geology**















-  Quaternary alluvium and alluvial terraces
-  Quaternary swamp, lake and lagoon deposits
-  Quaternary dune deposits
-  Quaternary colluvium
-  Quaternary Bridgewater Formation (ancient dune)
-  Quaternary Newer Volcanic Group basalts
-  Neogene sands, silts & clays
-  Neogene limestone, marl, mudstone
-  Neogene? older volcanics
-  Palaeogene gravels, sands, silt & clay
-  Cretaceous sandstone, mudstone
-  Fault
-  Fault (inferred)
-  Monocline

Figure 3. Regional geology of the Bellarine Peninsula

In the last glacial maximum (LGM) during the Pleistocene (~20Ka), sea levels dropped to around 150 metres lower than present, during which time a large barrier dune formed across southern Australia. Remnants of this dune - the calcarenite limestone of the Bridgewater Formation - form the coastal headland at Barwon Heads.

At the end of the ice-age, sea levels rose rapidly and by 6000 years before the present time, sea levels were around 2 metres higher than today. During this time a shallow seaway stretched across the Moolap Sunkland connecting Stingaree Bay and the Barwon estuary, before sea levels fell to their present levels around 3000 years ago. The receding Holocene coastline left behind a series of arcuate dunes as the lower Barwon estuary took its present form.

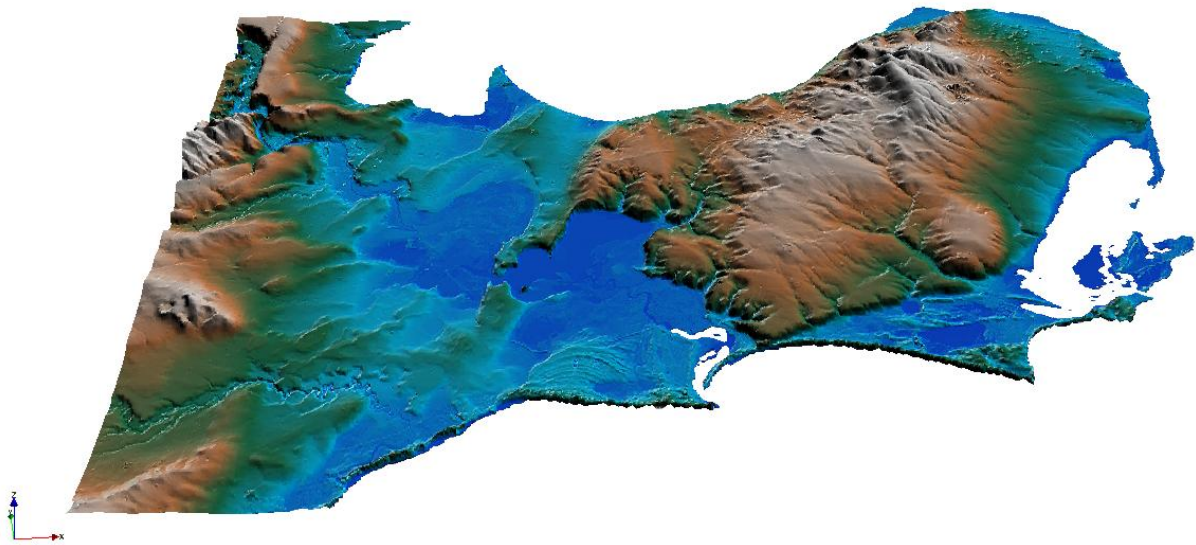


Figure 4. Terrain detail of the Bellarine Peninsula.

The sediments underlying the lower Barwon River, wetlands and estuary are geologically young, probably less than 5000 years old. The oldest are marine sands, muds and shell beds deposited in a marine or shoreline environment. These are overlain by and intercalated with muds and sands of fluvial, lacustrine and estuarine origin. The most recent sediments are silts, clays and sands that are attributed to landscape changes in modern times, since European settlement and widespread land-use changes in the catchment. During the mid-19<sup>th</sup> century extensive gold mining and associated erosion in the upper catchments of the Leigh and Moorabool rivers were rich sources of sediments, followed by agriculture and associated soil erosion. Modern sediment provenance studies have shown that a little over 50% of the sediment is sourced from the Moorabool River catchment, less than 25% from the Barwon River, 15% from the Leigh River and 5% is locally derived.

## **Hydrogeology**

The hydrogeology of the region, including flow systems, ground-surface water interaction and controls on water quality are the subject of collaborative research between the University of Ballarat (UB), RMIT University (RMIT) and Wakayama University, Japan. This research is mostly based on continuous logging of ground and surface water levels at a series of sites, and periodic sampling of waters for geochemical analysis.

### ***Conceptual model***

The research to date confirms that the interactions between the groundwater and surface water systems (both fresh and salt water) are quite complex. In plan view (Figure 5), the conceptual groundwater flows are shown flowing south east through the basalts of the Mt Duneed flow towards the outlet at the mouth of the Barwon River, where the basalt is exposed in the shore platform at Barwon Heads. The groundwater increases in salinity as it moves downgradient, with the result that the bores constructed in the basalts at the western end of Hospital Swamps record salinities, measured as electrical conductivity (EC), of <20dS/m, whereas the bore in basalt at the eastern end of the swamps records salinities of >50dS/m. The eastern end of the basalt aquifer probably receives some marine groundwater input but the geometry of the saltwater-freshwater interface is not known.

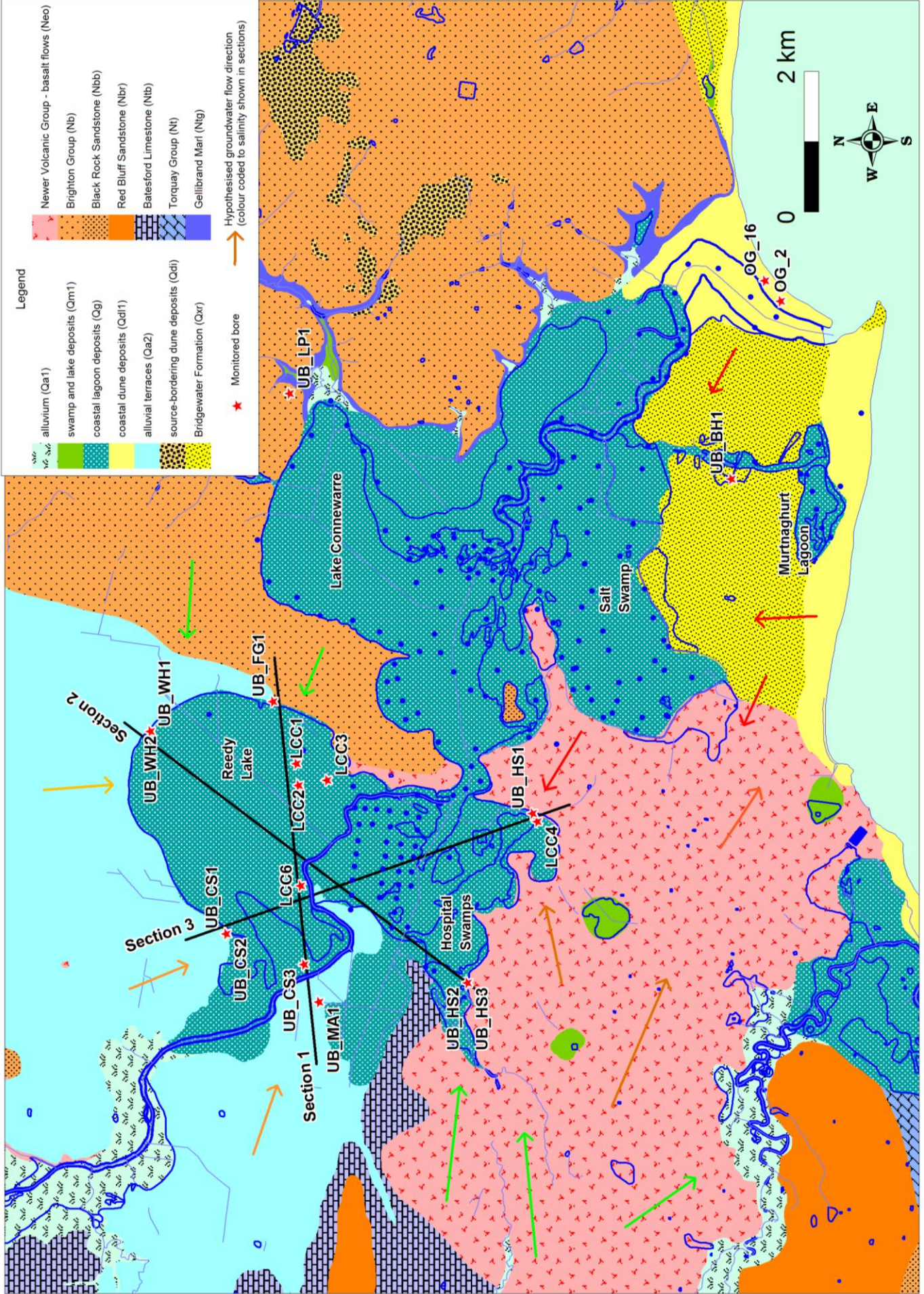
North of the river, the shallow saline groundwater is assumed to flow towards the northern and western edges of Reedy Lake under very low gradients. The shallow bore on the northern boundary of the lake shows salinities >50dS/m and is higher than the deeper groundwater at the same location (<30dS/m), suggesting that low flow rates combined with evaporation of discharge has concentrated the salt (i.e. similar to a stagnation zone). On the western side, the sandier aquifer materials in a palaeochannel from the north and the proximity to the Barwon River have probably combined to reduce the salinity to <30dS/m. Refer to the cross sections (Figure 6) for variations in salinity with depths.

On the eastern side of Reedy Lake groundwater may be contributed from the inferred fault zone, or flow through the uplifted materials of the Bellarine Block, or both. The salinities on the eastern edge of the lake are recorded as <40dS/m.

Lower in the system towards Salt Swamp and the Barwon Estuary, the groundwater appears to be strongly influenced by the marine tidal system. Bores located on the Ocean Grove spit confirm that the highly saline groundwater (seawater) flows inland from the coast along the fractured volcanic rocks of the Mt Duneed basalt flow. A tidal response is strongly evident in the time-series waterlevels in these bores.

The monitored variations in waterlevels and salinities show that in general the salinities of all bores are relatively high when compared to the surface water, and some exceed seawater salinities. Bore LCC6, adjacent to the inlet channel from the Barwon River to Reedy Lake, is the only bore where the groundwater is consistently in the range of surface water salinities. The groundwater intersected by the bores on the eastern side of the system is generally as saline as seawater or even higher. The bores with the greatest fluctuations in salinity are those on the northern and western fringes of Reedy Lake.

An additional 7 bores have just been constructed in the region with support from the City of Greater Geelong.



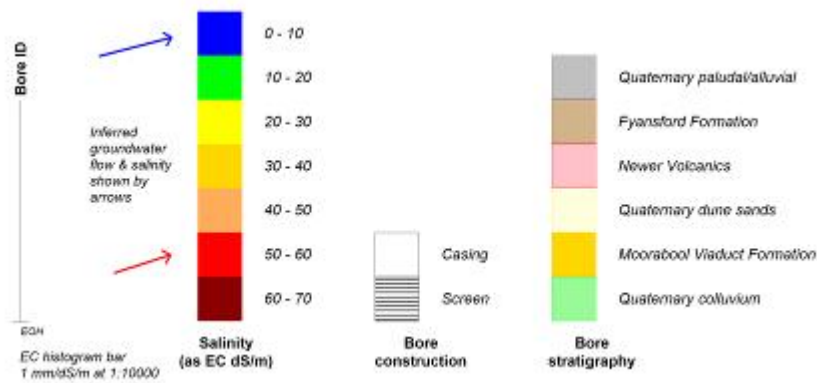
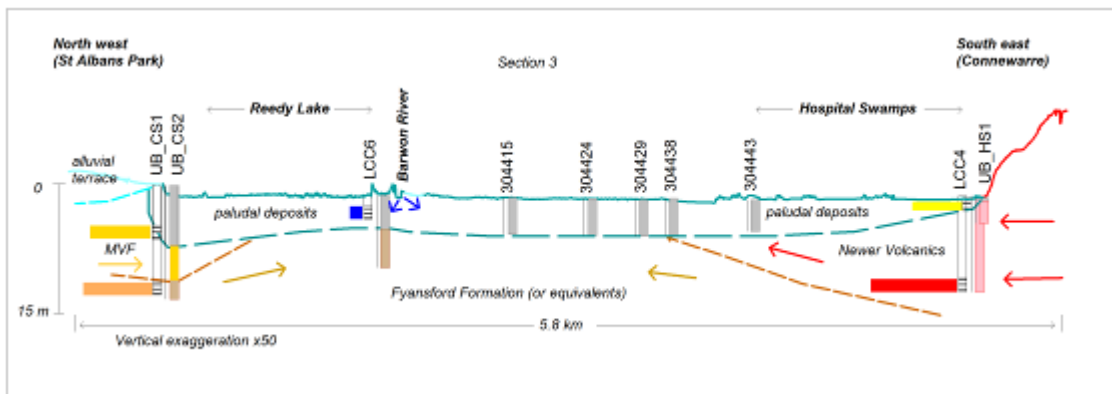
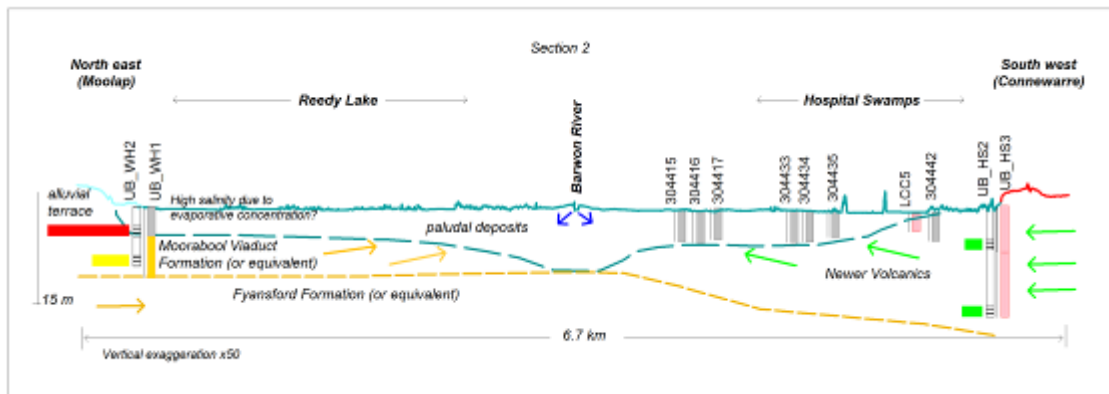
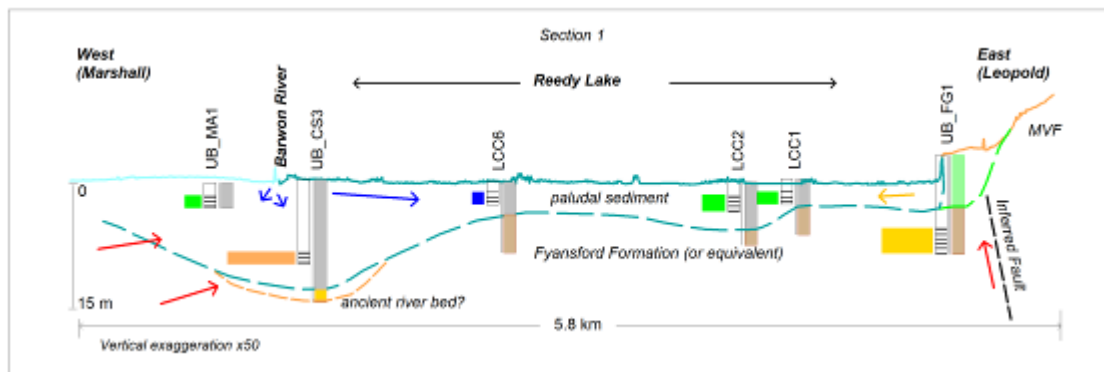


Figure 6. Sections showing conceptual models of groundwater flow in the LCC (section locations shown in Figure 5)

### Ground-surface water interaction

The hydrographs of the bores in Reedy Lake show that the groundwater levels in LCC1 & LCC2 - both of which are situated in the lake close to the 'big hole' - respond in concert with the lake levels. There is very little lag time between the raising or lowering of the lake level and the corresponding response in these two bores. By contrast, bores LCC6 - upstream of the barrage near the river and inlet channel - and LCC3 - downstream of the barrage and between the lake and the river estuary - display more complex responses. In both cases the waterlevels in the bores track the river levels until the river stops flowing (which occurred around the month of March in 2007, 2008, 2009 and 2013). When the river flows cease, the waterlevel in both bores continues to drop to 0.5m to 1m below AHD. As the river flows return and the river levels rise, the groundwater in each bore takes approximately 3 to 4 months to recover to the same level. This enigmatic behaviour is as yet unexplained. One theory is that there is a subsurface hydraulic barrier around 0.2m AHD which prevents the river water recharging the groundwater at low flow (or no flow), but the groundwater has a discharge point lower in the system (perhaps via palaeochannels? or leakage to the basalt?). The implications of this are that the lower reaches of the river behave as a losing stream at most times of the year, which is counterintuitive to the typical behaviour expected for the lower reaches of a river. More research is required.

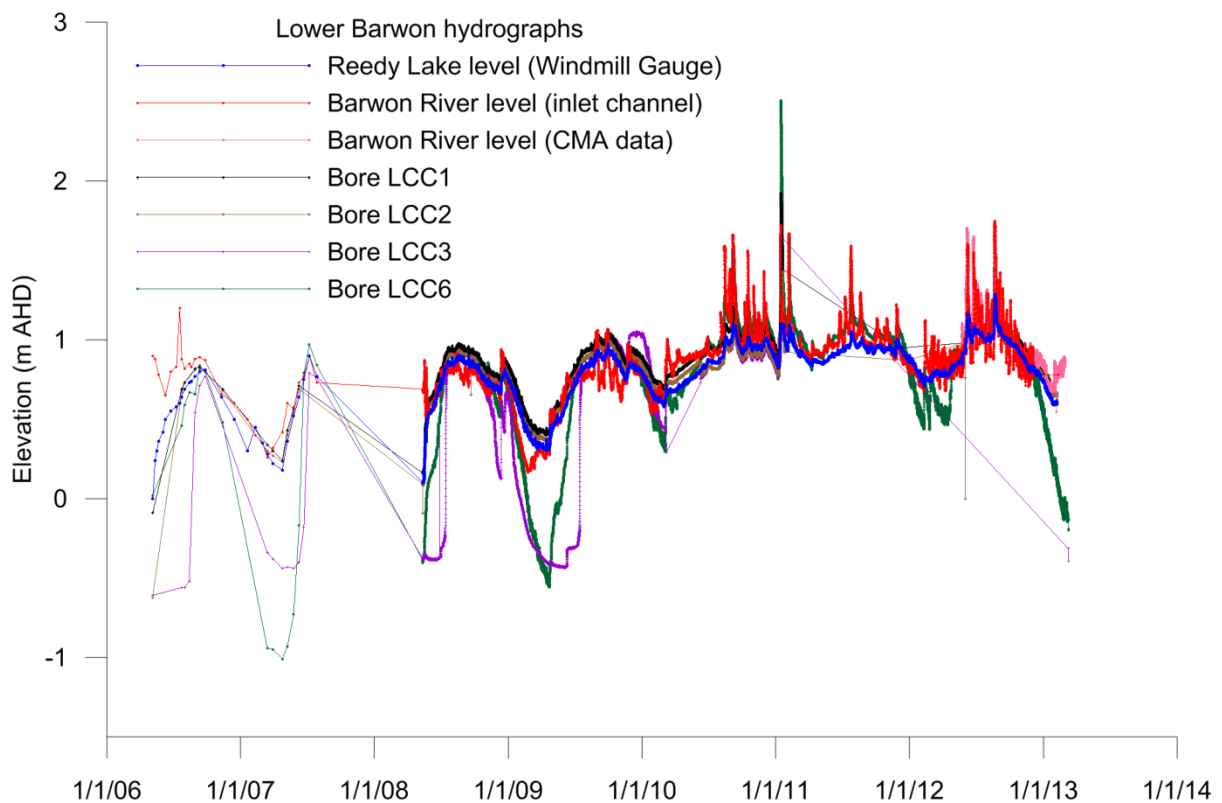


Figure 7. Surface water and groundwater levels compared.

When groundwater levels have been closely monitored (e.g. 15 minute intervals) some interesting signals can be seen in the hydrographs, such as a diurnal response to transpiration by the phreatophytic vegetation (where the monitoring bore is in the reed beds), and a tidal response for the bores close to the ocean.



Figure 8. The Lower Barrage in the river stops sea water from moving upstream.

*Note the fish ladder recently constructed on the right-hand side.*

### ***Geochemistry and isotopes***

Samples for major ion geochemistry and stable isotopes of water ( $\delta^{18}\text{O}$  &  $\delta^2\text{H}$ ) have been collected from a range of groundwater and surface water sites between 2009 and 2013. Alongside the physical hydrogeology, these give a greater understanding of the flow systems, sources of groundwater, and salinity in different parts of the system. Groundwater and surface water salinity exhibit a wide range, and salinity sources include marine water from modern and/or palaeo incursion, evaporation, plant transpiration and water-rock interaction.

A plot of groundwater EC and  $\delta^{18}\text{O}$  values in different parts of the system (Figure 9) is used to interpret the dominant salinity source(s) based on the isotopic signatures. Groundwater and surface water in the region broadly fall into 4 groups:

*Group A:* Fresh surface water and groundwater, fed by runoff from the Barwon River and occurring in Reedy Lake, Hospital Swamps and a localised pocket of fresh shallow groundwater adjacent to the river (Bore LCC6). This water has undergone minor amounts of evapo-concentration, reaching maximum salinities of ~5 dS/m.

*Group B:* Marine origin surface water and groundwater, found at the mouth of the Barwon River and periodically in Lake Connewarre, also in the groundwater in the Newer Volcanics aquifer some kilometres inland of the coast, such as in HS1, southeast of Hospital Swamps. This water has chemistry and stable isotopic signatures characteristic of seawater.

*Group C:* Regional groundwater, containing salinities between 10 and 50 dS/m, with one sample locally >70dS/m. This water has high salinity, but stable isotope values indicate that the source of salinity is not marine water; rather it is a result of salt accumulation from the aquifer matrix and/or concentration of solutes by plant transpiration and ion exclusion

*Group D:* Groundwater in the bed of Reedy Lake with intermediate salinities (10 to 30 dS/m), which could constitute a mixture of fresh surface water from river or lake leakage and marine water, or, fresh surface water recharged into the aquifer and subsequently subject to plant transpiration (which does not fractionate stable isotopes of water - Clark and Fritz 1997).

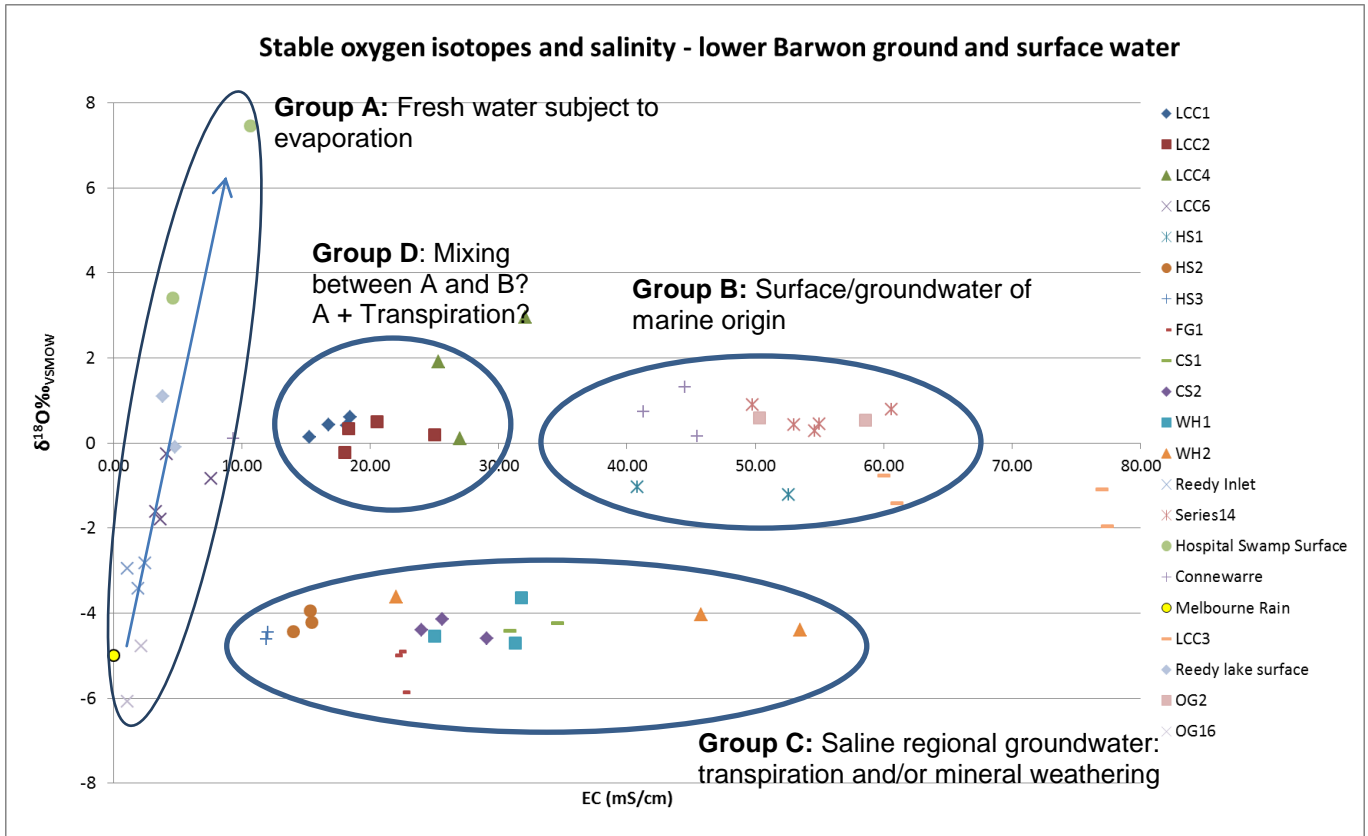


Figure 9 – Salinity and stable oxygen isotope compositions of ground and surface water samples in the lower Barwon wetlands. Water falls within 4 major groupings with different sources of salinity

Further studies into the distribution of salinity with depth in the aquifer system by pore water sampling and/or geophysical techniques could reveal more about the interactions between vegetation and groundwater salinity in the system. If groundwater salinity, as suspected, is a major determinant of the ability of different vegetation species to thrive, then integration of groundwater and surface water management strategies may be able to assist in meeting management objectives for the wetlands.



Figure 10. Bore LCC2 situated in Reedy Lake.

## Hydrology-Ecology relationships

The Lake Connewarre reserve is the largest area of native vegetation on the Bellarine Peninsula (3411 hectares). It is characterised by wet coastal complex vegetation on saline soils with sharp zonal boundaries between structural forms and plant assemblages. The surface and groundwater hydrology is a major control on the distribution and health of plant and animal communities in the system. The seasonal availability and salinity of water is a key control on types of vegetation found throughout the region; the plant communities exhibit zonation that is largely dependent on the salinity of available water. A number of salt-tolerant phreatophyte species are common in the area, such as Lignum and Beaded Glasswort – both of which tolerate high salinities and shallow water tables. Figure 11 shows the results of vegetation mapping conducted around Reedy Lake, with the local groundwater salinity values included. Figure 12 depicts a typical zoned pattern of vegetation, controlled by salinity of the available water ranging from saline shallow groundwater to fresher surface water.

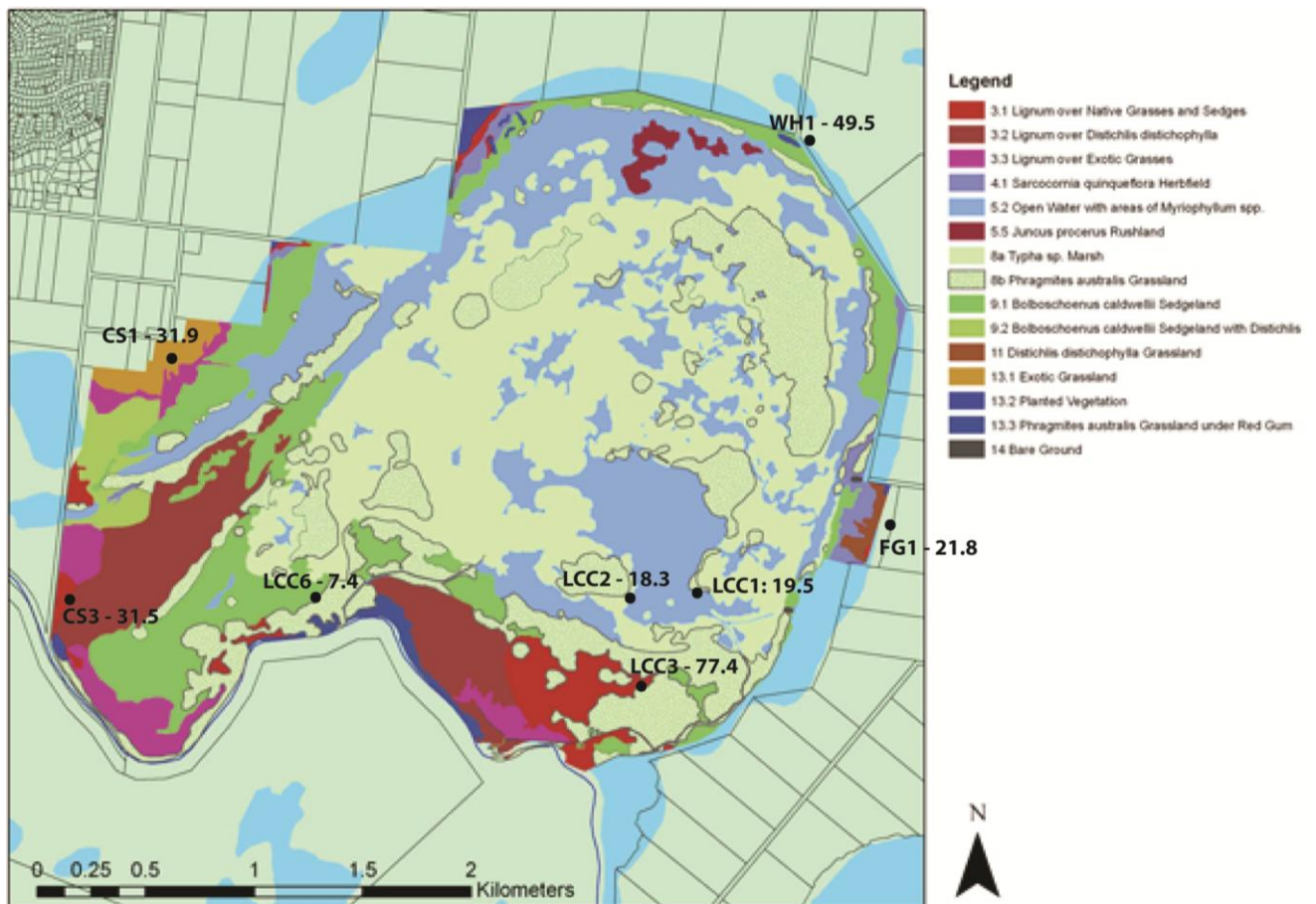


Figure 11 – Reedy Lake vegetation map and groundwater salinities (EC in dS/m; typical ocean water = 49 dS/m). Fresher groundwater and/or access to fresh surface water encourage proliferation of reeds, particularly *Typha Orientalis*.

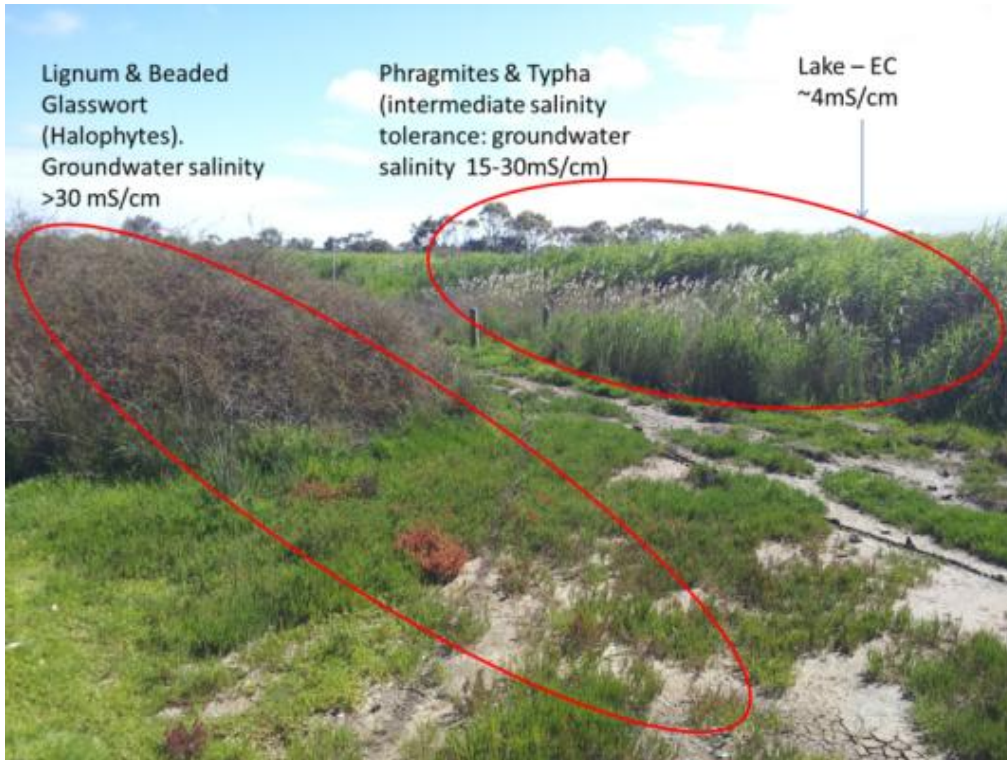
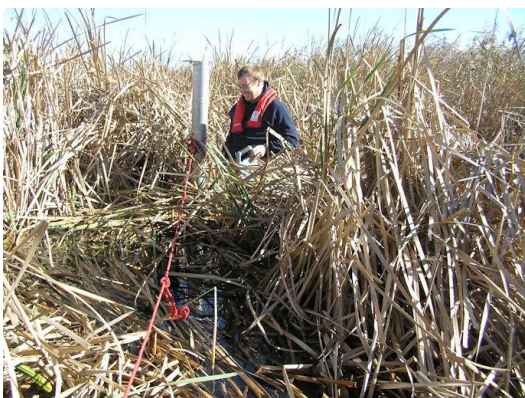
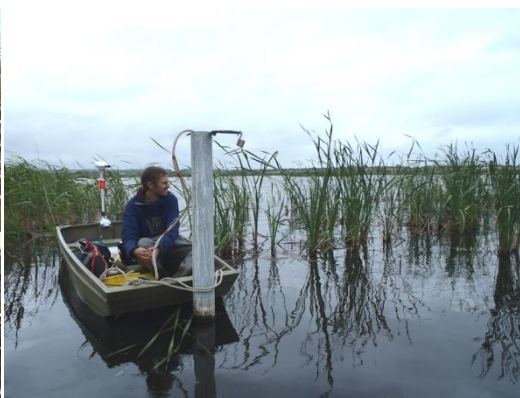


Figure 12 – Photograph showing typical zonation of vegetation type at the wetland edge (picture taken at Hospital Swamps by M. Currell).

Regulation of the Barwon through construction of the breakwater resulted in a change from predominantly saline (estuarine) to fresh (river) inflows in Reedy Lake. This has encouraged the proliferation of reeds, particularly *Typha Orientalis* and *Phragmites Australus*, at the expense of other species and the amount of open water in the lake. Controlling the spread of these reeds, and encouraging diverse vegetation communities is one of the management objectives for the system. With future changes to surface and groundwater hydrology in the area occurring due to urbanisation and sea-level rise, the prediction and management of future changes in the distribution and health of the vegetation communities poses a major challenge.



June 10<sup>th</sup> 2010



December 21<sup>st</sup> 2011

Figure 13. Example of the changes in reeds around Bore LCC2, due to water depth.

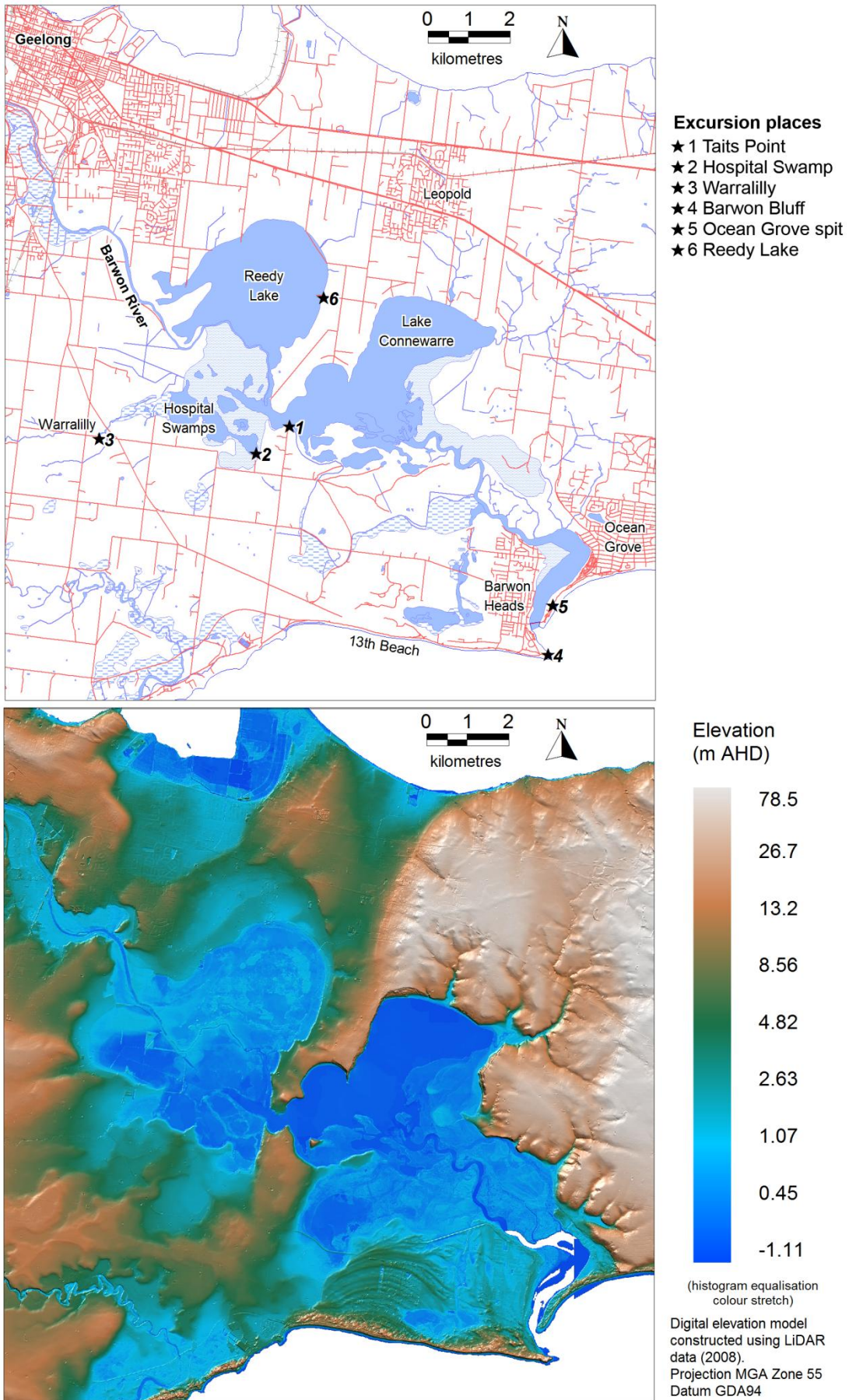


Figure 14. Excursion region.

## Excursion notes

### 1. Tait's Point, Lake Connewarre view

Lake Connewarre forms a large part of the Barwon estuary, a permanently open estuary extending for 19 km 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 50cm. Lake Connewarre (and indeed, 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.



Figure 15. Lake Connewarre delta (looking to the NNW).

Historical evidence and scientific studies have documented the accumulation of sediment in the lake since the widespread land-use changes in the catchment from the mid-19<sup>th</sup> Century. The quality of this sediment is poorly researched, especially in relation to the contaminants.

At various times Lake Connewarre has been observed to have extensive meadows of the seagrass *Zostera muelleri*. However, it is thought that the extent of seagrass beds within the lake has waxed and waned over the past twenty years in response to the constant remobilisation of sediments (the lake is shallow) and the variable inputs of freshwater depending on the river inflows.

The Barwon River estuary supports the westernmost population of white mangrove (*Avicennia marina* var. *resinifera*) in Victoria, which occur as stunted shrublands along the lower Barwon, with patches extending up to the exit of Lake Connewarre.

The terrestrial vegetation surrounding the Lake Connewarre Complex is diverse and represents some significant vegetation communities and species, such as *Melaleuca lanceolata* scrub (moonah woodland).

## 2. Hospital Swamps

Hospital Swamps is the name given to five shallow (<0.5m) wetlands that are filled by water diverted from the Barwon River as well as some local runoff. Prior to the installation of the water supply channel from the Barwon River in 1983 the swamps would fill only when the river flooded, or after wet weather periods. The swamps dry quickly when water supply is limited and the lake water becomes increasingly saline as the water is evaporated.

The swamps are located on the basalt and overlying Quaternary sediments. Groundwater bores at the eastern end of the swamps intersect highly saline water, with EC values >50mS/cm. Some hyporheic exchange between the lake water and groundwater is likely, with the groundwater immediately beneath the lake floor recording much higher salinities (EC >30mS/cm), than the fresh water in the lake (EC <3mS/cm). By comparison on the western side of the swamps, groundwater bores in the fractured basalt aquifer intersect groundwater with lower salinities EC <20mS/cm.

During summer and autumn as the freshwater in the wetlands evaporates, the saline groundwater discharge to the lake bed accumulates salts in the soils that are cyclically flushed again when the freshwater returns in the spring and winter seasons. This seasonal salinity supports a gradational vegetation ecology as illustrated below.

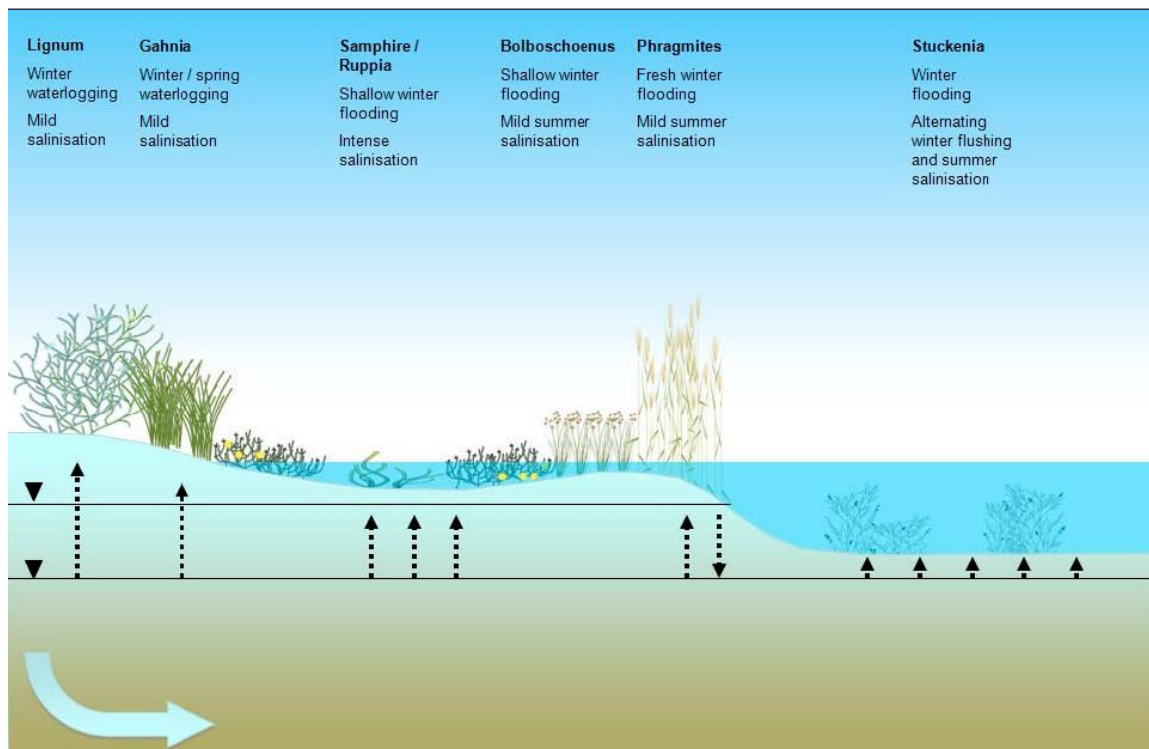


Figure 16. Vegetation relationships with flooding and groundwater in Hospital Swamp.

### 3. Warralilly (Armstrong Creek urban growth area)

The Armstrong Creek urban growth area was announced by the Victorian Premier in 2008 to create 22,000 new homes for 54,000 people. It is the largest contiguous growth area in Victoria, consisting of 2,500 hectares of developable land.

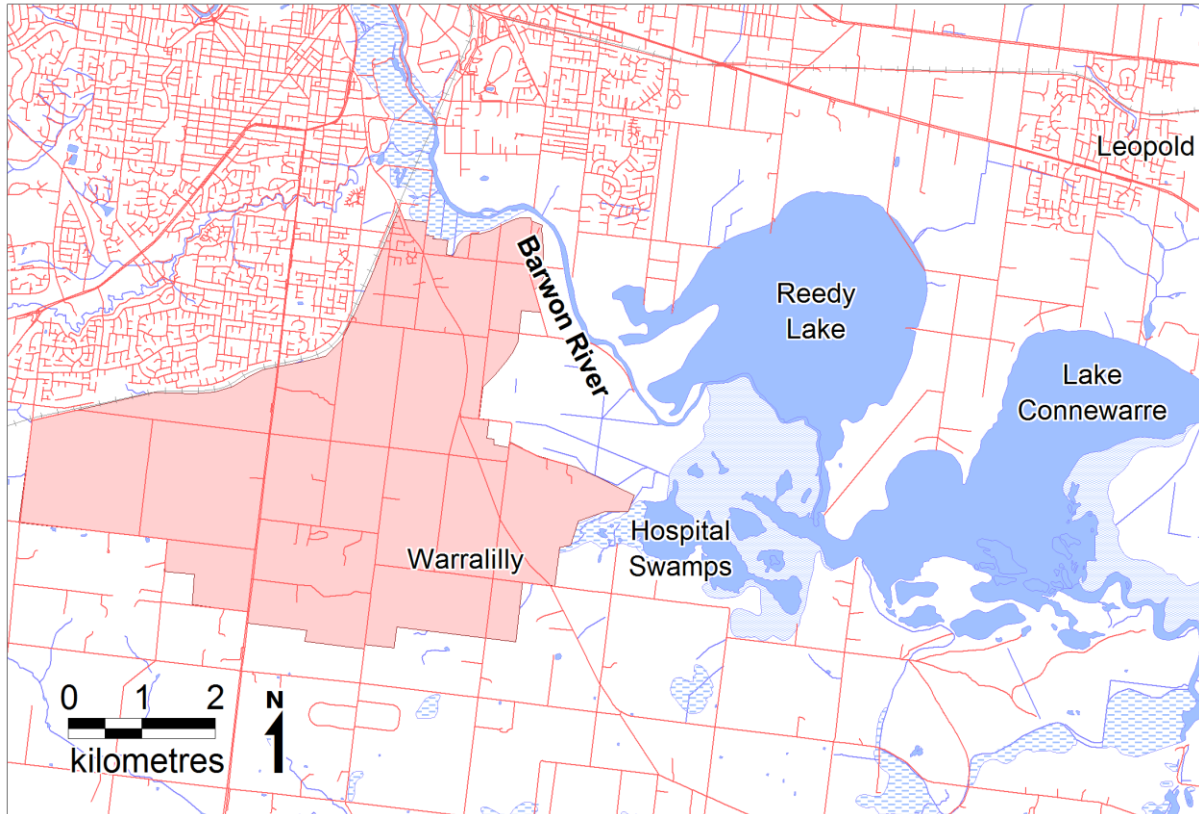


Figure 17. The urban growth area (shaded) of Armstrong Creek

The local municipal government - the City of Greater Geelong - has a vision for Armstrong Creek to be developed into a sustainable community that sets new benchmarks in best practice urban development. The strategic development plans intend to protect natural and cultural features, including the adjacent Ramsar-listed wetlands of Hospital Swamps. The plans include:

- capturing and recycling storm water,
- construction of water storage ponds beside public open spaces for irrigation use,
- the use of water sensitive urban design,
- the use of Class A recycled water via a dedicated 'purple pipe' scheme, and
- rainwater tanks for households and business.

The current plan includes some stormwater disposal into Hospital Swamps.

During the construction phase at Warralilly it became apparent that a shallow, saline watertable was present across the region. The artificial lakes constructed for stormwater mitigation partially filled with groundwater, reducing the freeboard for storm water capture and affecting the quality of the water intended for reuse (irrigation).

#### 4. The Barwon Bluff

The Bluff at Barwon Heads is a prominent coastal headland which forms the southern bank of the mouth of the Barwon River. Barwon Heads has been a popular holiday destination since the late nineteenth century, and The Bluff is a local tourist attraction and national cultural and heritage asset.



Figure 18. The Barwon Bluff.

The Bluff represents the lee side section of a Pleistocene dune system - the Bridgewater Formation - which consists of a thick sequence of aeolian calcarenite, interspersed with calcrete layers. The Bridgewater Formation unconformably overlies basalt (east) and limestone (west), which forms undulating and rocky shore platforms ('reef'). The reef area (17 hectares) was declared a Marine Sanctuary in November 2002 to protect a large variety of marine plants and more than 35 species of intertidal invertebrates, and dozens of fish species.

From the Barwon Bluff a view of the overall landscape of the lower Barwon River, estuary and wetlands can be seen.

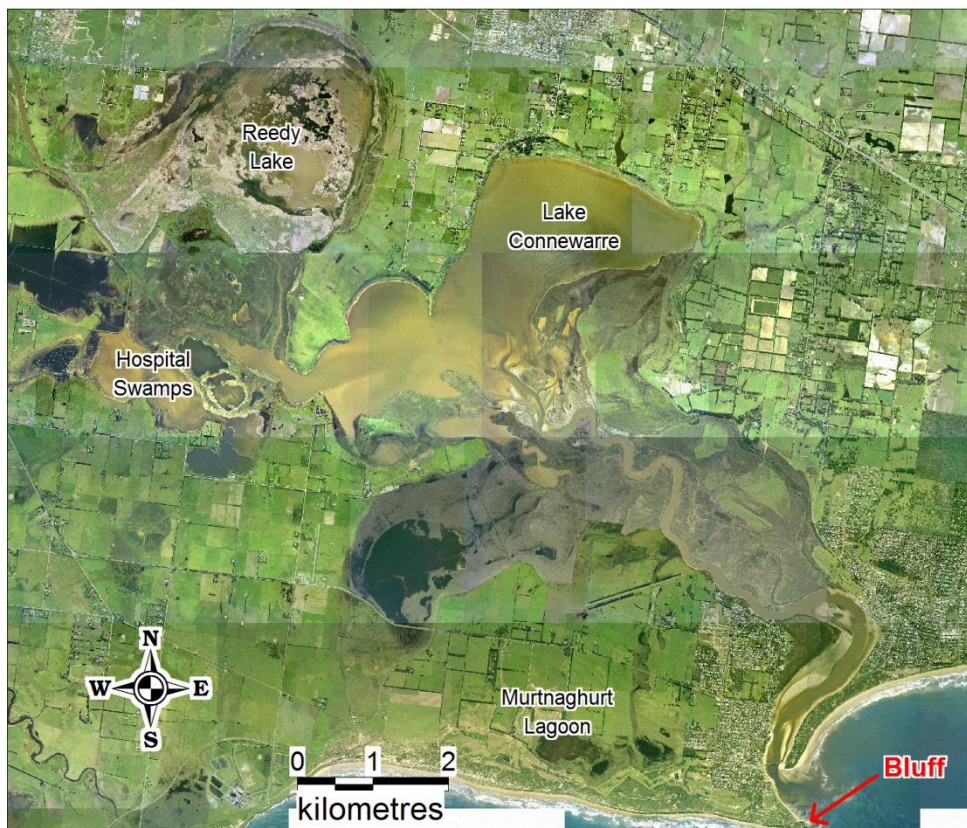


Figure 19. Aerial image mosaic of the excursion area.

## 5. The Ocean Grove spit

The Ocean Grove spit is a long, low sand ridge (dune) that divides the Barwon River estuary from the sea. The spit is a popular holiday location, spanning the calm riverside beach for wading and the ocean beach (Raffs Beach) for surfing. The formation of the spit initially seems counter to the dominant longshore sand drift (to the northeast), but has formed due to the refraction of waves around the Bluff. The swell arriving from the south or southwest is refracted  $>90^\circ$  resulting in a localised reversal of the sand drift and the growth of a barrier spit. The sand dune overlies estuarine clays which in turn overlie the basalt of the Mt Duneed flow.

Bores were drilled on the spit in 2007 for the geotechnical investigation prior to the construction of the main trunk sewer. Two of these bores were retained by the Barwon Coast Committee of Management for the research being conducted by UB and RMIT. Bore OG2 is 19.7m deep, and constructed as a piezometer, screened from 16.7 - 19.7 in the basalt aquifer. Water levels logged in the bores show the response to tides.

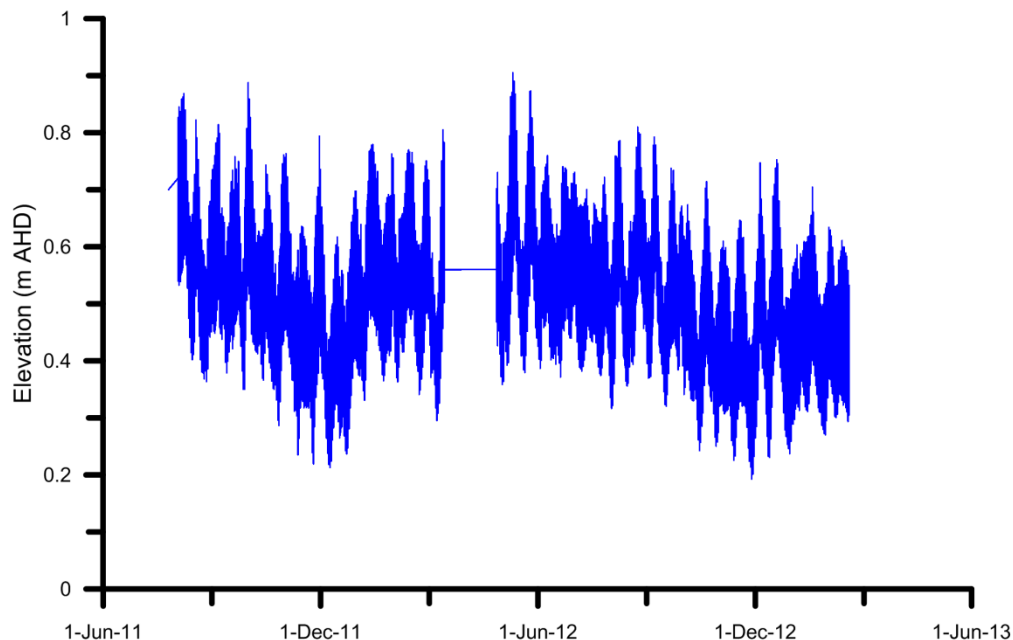


Figure 20. The tidal influence seen in the hydrograph for Bore OG2.

*Note that data has been barometrically compensated.*

The groundwater in the bore has the chemistry of seawater, suggesting that the bore is screened below the freshwater interface with the saltwater. Density layering in the bore results in stratified salinity when the bore has not been pumped for some time.

## 6. Reedy Lake

Reedy Lake takes its name from the abundant water plants that cover this shallow wetland. Originally the lake was filled by periodic river flooding, high tides and runoff from the local catchment. In 1970 flap gates were installed on the outlet to the estuary, excluding saline water and changing the ecology to a particularly rich flora by the time it was included in the Ramsar Site (1982). Between 1990 and 1993 there was a rapid loss of reedy vegetation, creating more open water. However, this trend rapidly reversed in the following years, with a dramatic increase in the area covered by reeds.

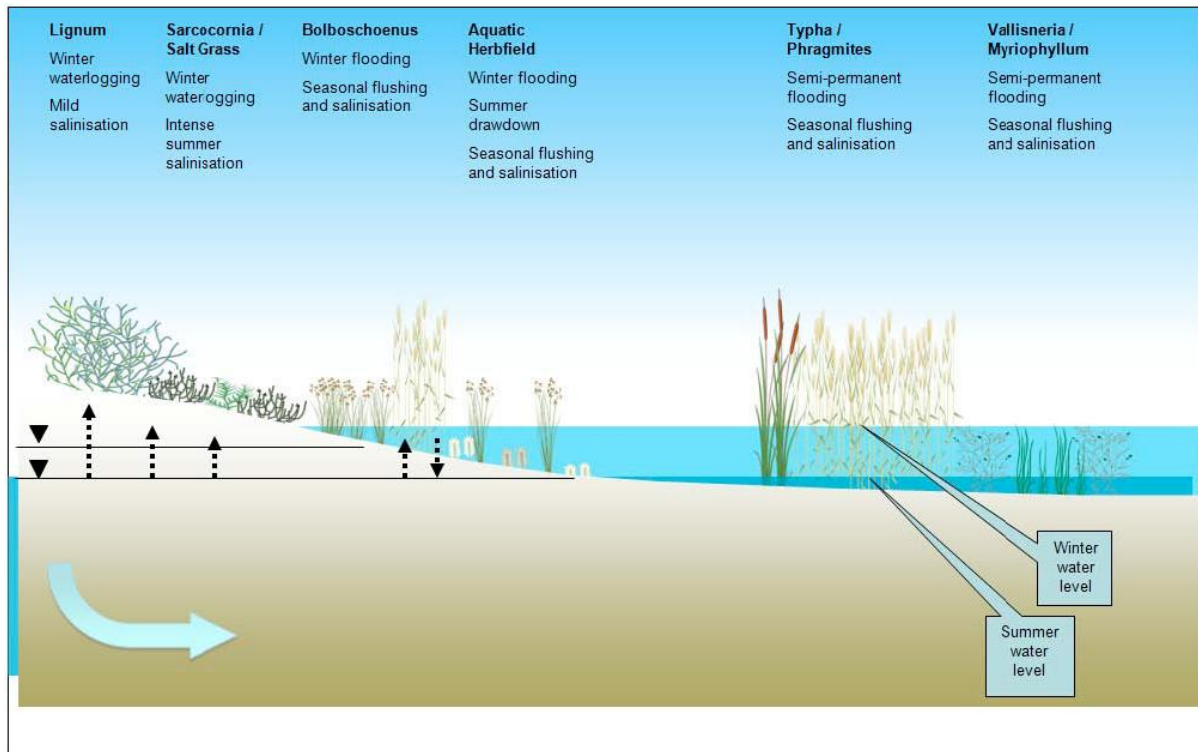


Figure 21. Vegetation relationships with flooding and groundwater in Reedy Lake

The changing vegetation is attributed to the impacts of grazing by livestock (from 1840s to 1983) and the introduction of the European Carp (*Cyprinus carpio*). Carp are controlled by exclusion screens at the inlet gate and by periodically draining the lake. In 1994 it is estimated that up to 10,000 fish were stranded and in 2005 approximately 2,500 large carp were stranded when the lake was drained.

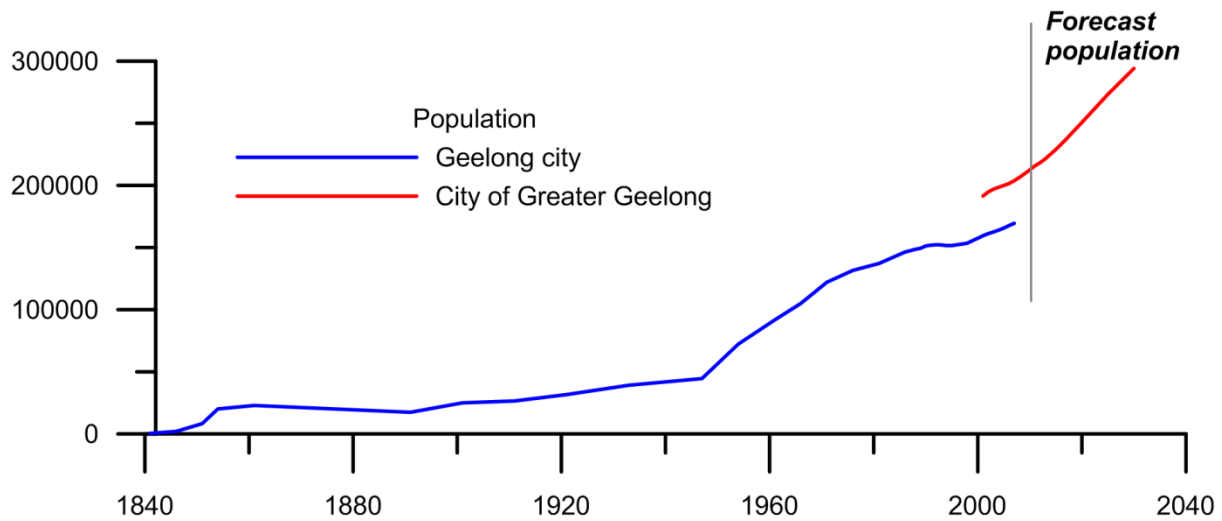
Research into the hydrogeology of Reedy Lake continues with water level logging, chemical and isotope studies. The mosaic of vegetation in the lake and environs is believed to be related to the salinity of the groundwater as the majority of the plants are phreatophytes. The salinity of the groundwater varies considerably, from EC <3.5mS/cm near the inlet channel to EC >70mS/cm near the outlet channel. Bores in the lake record salinity in the groundwater beneath the lake bed of around EC 15 - 20mS/cm, while the lake water rarely exceeds 5mS/cm EC. The responses of the groundwater levels and salinity to the river levels and estuary levels is quite complex and not yet fully understood.

Reedy Lake is used for duck hunting, commercial eel fishing, recreational fishing, passive recreation (especially bird watching), scientific research and environmental conservation.

## About the City of Greater Geelong

Established in 1836, now Victoria's second largest city

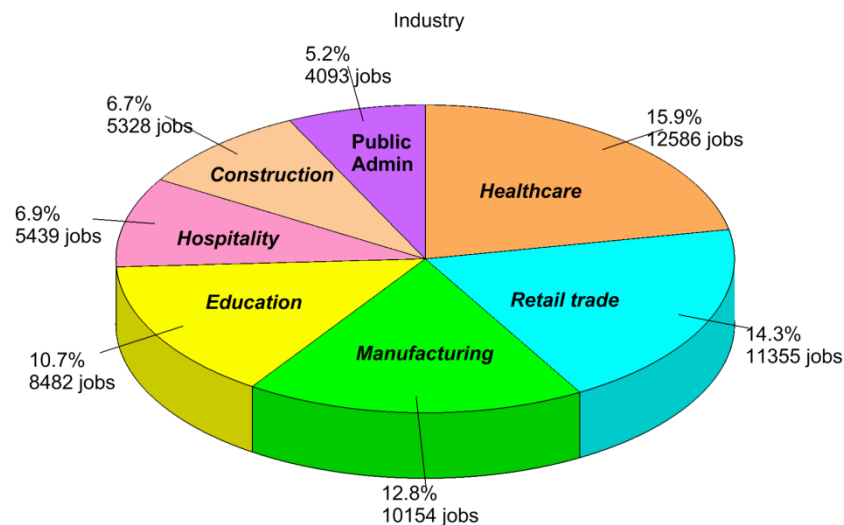
**Population** approx 220,000



**Climate:** Temperate, Mediterranean warm dry summers, cool wet winters

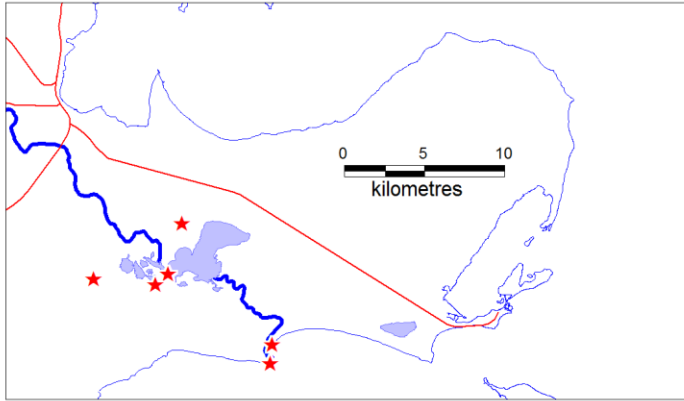
Mean max temp 19.3°C Mean min temp 9.0°C Annual rain 530mm

**Industries:** approximately 102,000 employed (unemployment ~5%)



**Water:** Urban water supplies and sewerage services are supplied by Barwon Water. Geelong's water supply is sourced from **surface water** - the upper Barwon River, the Moorabool River; **groundwater** - the Barwon Downs borefield and the Anglesea borefield; and **recycled water** - the Black Rock treatment plant. The Melbourne to Geelong pipeline will supply water from Melbourne's **desalination** plant in the future.

**Environment:** Environmental management is shared between the Commonwealth of Australia (Department of the Environment), State of Victoria (Department of Environment and Primary Industries) and the City of Greater Geelong. Parks Victoria, the Corangamite Catchment Management Authority, the Victorian Environmental Water Holder, EPA Victoria, Southern Rural Water, Barwon Water and the Barwon Coast Committee of Management are the main on-ground managers and stakeholders.



**Excursion places**

- ★ 1 Taits Point
- ★ 2 Hospital Swamp
- ★ 3 Warralilly
- ★ 4 Barwon Bluff
- ★ 5 Ocean Grove spit
- ★ 6 Reedy Lake

