CORANGAMITE CMA

ENVIRONMENTAL FLOW DETERMINATION FOR THE BARWON RIVER

Site Paper

Lloyd Environmental

FLUVIAL SYSTEMS

FLUVIAL GEOMORPHOLOGY
RIVER REHABILITATION
ENVIRONMENTAL FLOWS
CATCHMENT HYDROLOGY

ecological associates pty ltd

Table of Contents

1. INTRODUCTION

The Barwon River is identified as a fully-allocated catchment where the water reserve will be established initially by recognising existing entitlements, capping consumption, and applying a moratorium to new diversions. In a state-wide assessment, the Barwon has been identified as one of 21 streams which require the development of a stream flow management plan. The Victorian Government White Paper 'Securing Our Water Future Together' provides the policy underpinning for the water needs of the environment by establishing an Environmental Water Reserve.

The Corangamite CMA is responsible for the overall river health of the Barwon River and the assessment of the environmental flow needs of this river, including its internationally significant lakes and wetlands in its estuary zone. The CMA is responsible for determining ecological objectives for flow-dependent ecosystems, which will be used by DSE to set priorities and develop options for water recovery.

The Barwon is a major water supply for Geelong, the smaller urban centres, and farm water supply for the region. The system is significantly altered via extensive farm dam storages, on-stream reservoirs and many diversion licences. Inter-basin transfers occur from Lake Colac (via the Lough Calvert drainage scheme) and Lake Corangamite (via the Woady Yaloak drainage scheme) into the Barwon River.

Recent assessment of the ecological condition of the river, as part of the Corangamite River Health Strategy, has indicated that most reaches are in marginal to very poor condition, whereas a few streams in good or excellent condition are high in the catchment, above water supply storages. Wetland condition assessment (2004) has shown that most wetlands (60%) are either degraded or severely degraded, with only 15% being intact or pristine.

The estuary of the Barwon River, which includes Lake Connewarre, Reedy Lake and the lower Barwon, are internationally significant wetlands and regional, Victorian and Australian government agencies have a responsibility to protect and enhance these values.

The Corangamite CMA has commissioned Lloyd Environmental Pty Ltd, Ecological Associates Pty Ltd, and Fluvial Systems Pty Ltd to undertake this FLOWs study to gain an understanding of the role of water in the health and functioning of the freshwater and estuarine reaches of the Barwon River system. The study will classify the flows in each hydrological component, or reach, of the system, and predict the frequency, duration and seasonality of each flow band required to sustain the ecosystem. Quantification of these requirements, through a hydrological model, will allow the deficiencies between the required and current water regime to be prioritised and targeted by appropriate use of available environmental flows.

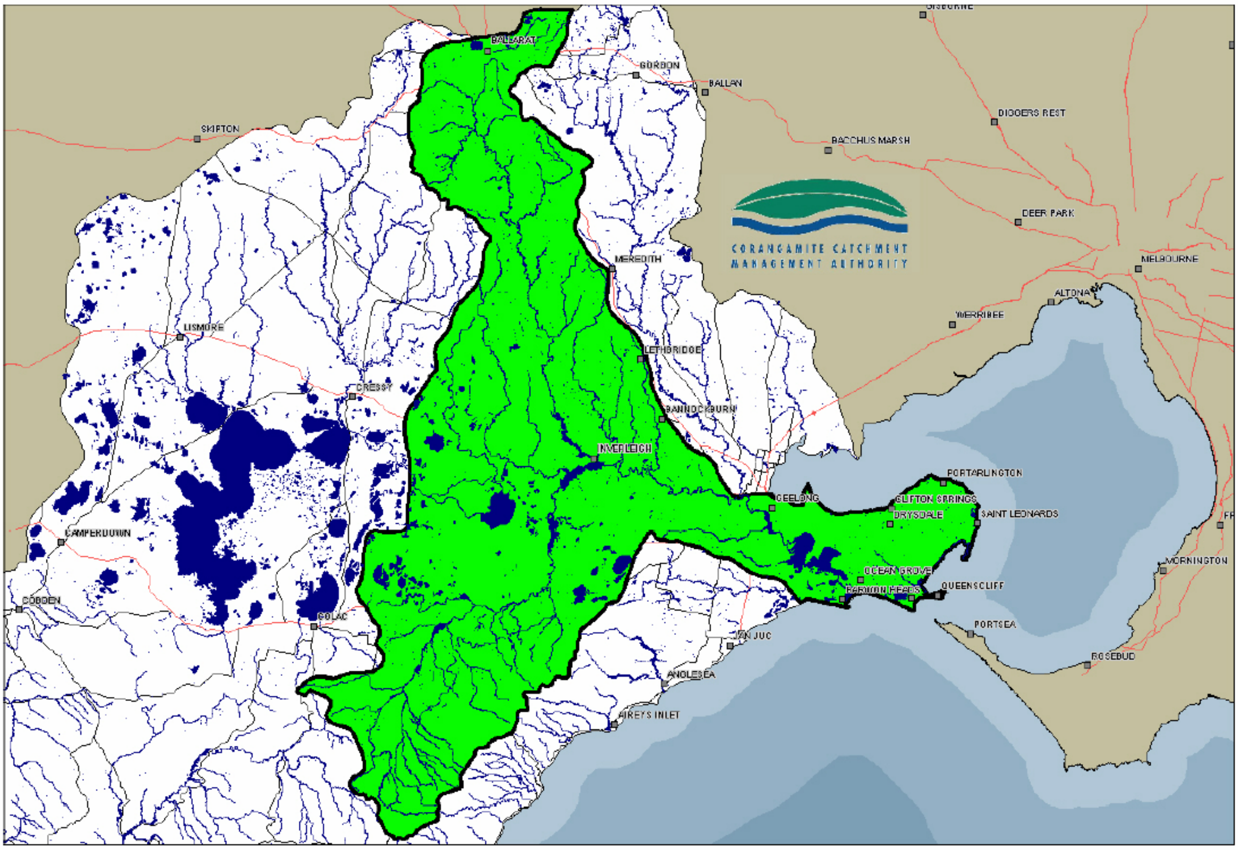

Figure 1: The Barwon River Catchment

1.1 Objectives

The overall objective of this project is to determine the environmental water requirements of the Barwon River, including Lake Connewarre and the Barwon Estuary, and to develop options to meet the environmental needs.

More specifically, this investigation will:

- ☐ identify water dependent environmental and social values within each reach;
- ☐ gauge the current health of the environmental values;
- ☐ identify the flow regimes that will maintain or enhance the environmental values;
- ☐ develop Environmental Flow Objectives that take into account current social, economic and environmental values of the river; and,
- ☐ recommend an environmental flow regime to meet the objectives.

1.2 Approach

The overall approach for the determination of the environmental recommendations for the Barwon River catchment follows the FLOWs methodology which was developed for and adopted by DSE as the standardised state-wide method for determining environmental water requirements in Victoria (DNRE 2002). The approach is shown in Figure 2 below:

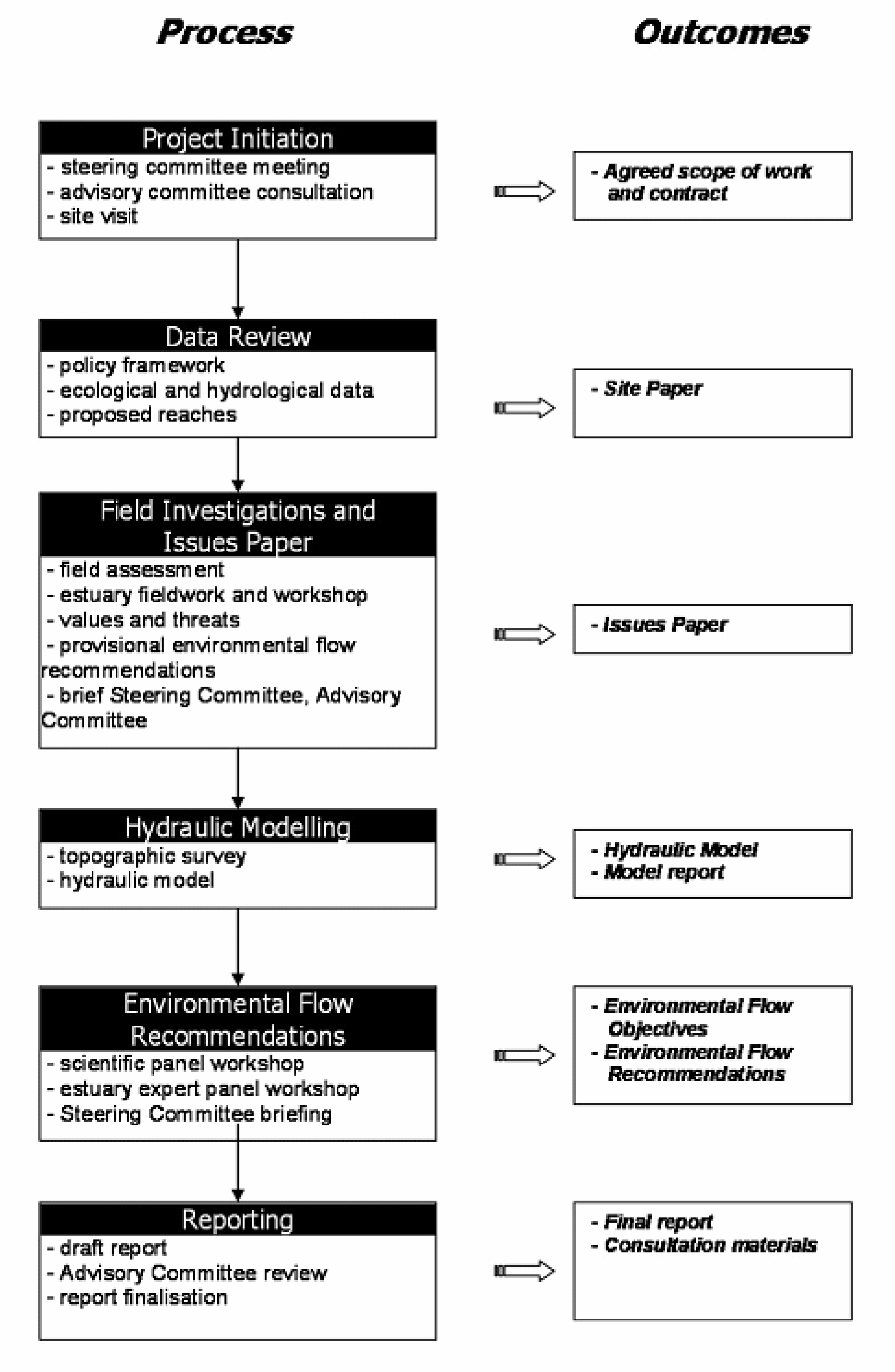

Figure 2: FLOWs Methodology indicating major project tasks and outputs.

The method involves the collation and review of the information through literature review, field assessments, consultations with agency and community members, topographic surveys of each site, hydraulic modelling, and a scientific panel workshop to make environmental flow recommendations. This document, the **site paper**, provides information on the ecology, geomorphology, hydrology and operation of the system and recommends the delineation of the reaches and sites for the Scientific Panel to assess.

1.3 Project Team

As with all FLOWs studies, a team of specialists are required to undertake this work. The Barwon River Environmental Flow Project team comprises:

- ☐ Lance Lloyd (Lloyd Environmental), fish & aquatic fauna ecologist;
- ☐ Dr Marcus Cooling (Ecological Associates), aquatic botanist;
- ☐ Dr Chris Gippel (Fluvial Systems), fluvial geomorphologist;
- ☐ Brett Anderson (University of Melbourne), hydrologist and hydraulic modeller;
- ☐ Associate Professor John Sherwood (Deakin University), water quality and estuary scientist;
- ☐ Dr Ashley Bunce, (Deakin University), waterbird specialist; and,
- ☐ Dr Mike Stewardson (University of Melbourne), environmental flow specialist and peer reviewer for this project.

1.4 Acknowledgements

This project could not have been possible without the assistance of and the valuable information supplied by the CCMA Project Manager (Simone Gunn), the Project Steering Committee, the Community Advisory Committee and the Expert Panel (Estuary). Their contribution is gratefully acknowledged.

2. REACH AND SITE SELECTION

2.1 Reach delineation

The Barwon River rises in the Otway Ranges and flows close to the townships of Forrest, Birregurra, Winchelsea, and Inverleigh before flowing through Geelong and joining the coast at Barwon Heads. The Leigh River, a major tributary, rises near Ballarat and joins the Barwon River at Inverleigh. Two other tributaries, Birregurra and Boundary Creeks, flow into the Barwon from the western part of the catchment. The environmental flow requirements of the Moorabool River, also a major tributary of the Barwon River, have been determined in previous studies and will not be revisited in this study. The Upper Leigh River is being examined by the Ballarat Water Resources Committee through two projects and is not being considered in this study (apart from the downstream effects in the mid and lower Leigh River).

Based on initial information, the Corangamite CMA divided the system into 9 reaches as follows:

1. Barwon River from West Barwon Reservoir to Conns Lane
2. Barwon River from Conns Lane to Leigh River confluence
3. Barwon River from Leigh River confluence to Pollocksford Weir
4. Barwon River from Pollocksford to upper estuary limit
5. Lake Connewarre and Reedy Lake, lower estuary
6. Birregurra Creek
7. Boundary Creek
8. Leigh River to Mt Mercer
9. Leigh River from Mt Mercer to Barwon confluence

This report has evaluated these reaches based upon the representativeness of the reach, channel morphology, topography, impacts on flow and the environmental assets of the system.

3. THE BARWON RIVER SYSTEM

This section of the site paper summarises the existing information on the vegetation, fish, hydrology and geomorphology of the catchment. This information will be used to assist the reach delineation and site selection process as well as assist the understanding of the environmental water requirements of the system.

3.1 Vegetation

3.1.1 Barwon River

The riparian zone of the Barwon River below the West Barwon River to the estuary is generally highly modified (un-named source). Native riparian vegetation has been extensively cleared and stock generally have unrestricted access to watercourses. Vegetation typically comprises scattered native species, primarily herbs, among pasture grasses other weed species. Significant remnants remain, however, such as a site between Birregurra and the junction of the east and west branches (Kinhill Stearns 1986, cited in DCNR 1995).

Native riparian overstorey species typically include *Eucalyptus camaldulensis, Acacia melanoxylon, A. dealbata, Callistemon seiberi, Leptospermum lanigerum, L. obovatum, Hymenanthera dentata* and *Muehlenbeckia florulenta*.

Exotic overstorey species include *Salix fragilis, Ulex europaea* and *Prunus* spp.

Native understorey species include *Poa labillardieri, Phragmites australis, Juncus* spp., *Bolboschoenus medianus, Isolepis* spp. and *Schoenplectus validus*. Species of conservation significance include *Persicaria hydropiper, Rorippa laciniata, Veronica serpyllifolia* and *Alternanthera denticulata*.

Species indicative of saline conditions in this area are *Muehlenbeckia florulenta, Selliera radicans* and *Apium prostratum*.

Weedy understorey species include *Cyperus eragrostis* and *Phalaris aquatica.*

3.1.2 Leigh River

Upstream of Mt Mercer the riparian zone of the Leigh River is highly modified. The streams of the Leigh River catchment primarily flow through agricultural land with some areas of forest, mostly pine plantations.

Salix sp. and other exotics grow extensively along streams in the Leigh Basin. Dense upstream of Ballarat, and sparser downstream of Ballarat. Gorse *Ulex europaeus* dominates the riparian zone along much of the river.

The river passes through a gorge between Mt Mercer and Shelford. The vegetation in this zone is relatively intact and supports dense stands of aquatic macrophytes (Mitchell 1990 cited in DCNR 1995). Parts of the areas surrounding the gorge have remnant native forest vegetation. Three riparian species of regional conservation significance are *Leptospermum obovatum, Rorippa islandica* and *Samolus repens.* The presence of *S. repens* is indicative of saline conditions.

Below Shelford the Leigh River becomes a lowland stream with a floodplain, meanders and strong depositional characteristics. The river supports remnant stands of *Eucalyptus camladulensis.* Sediment derived from upstream in the catchment is deposited in this reach, filling the deep holes that would be expected in this section and reducing variability in the stream bed. It has been reported that sediment smothers aquatic vegetation (Craigie and Associates 1989 cited in DCNR 1995). Stock have access to much of the stream channel but, where excluded, the stream has stable banks and riparian vegetation in good condition.

3.2 Fish

Fish are widespread and an important ecological component of the Barwon River catchment. At least 44 species have been recorded within the freshwater and estuarine sections of the Barwon system, however, these numbers will be augmented by marine species entering the estuary complex for long periods (DCNR 1995, Tunbridge 1988, DNRE Fish Database 2005).

These fish can be classified into four types, based on their habitat preference and migration habits. These are:

Freshwater species: Mountain Galaxias, Dwarf Galaxias, Yarra & Southern Pigmy Perch and Big-headed Gudgeons are generally restricted to the freshwater reaches of streams, however, Big-headed Gudgeons are sometimes found in the estuary. These species generally do not migrate, except for local habitat and feeding reasons. The exotic fish will be generally restricted to the freshwater reaches although Eastern Gambusia are able to within stand highly saline environments. Three species of native Australian fish from the Murray-Darling Basin Murray Cod, Golden Perch and Macquarie Perch have been translocated into the Barwon but are not known to have formed significant populations.

Euryhaline species: These are species that can live in both freshwater and estuarine habitats and include Blue Spot Goby, Congolli, and Small-mouthed Hardyhead. These fish can penetrate some distances up stream into freshwater and remain for their whole life cycle although all tend to breed in estuarine waters.

Migratory species: Most of these fish live in freshwater and migrate downstream to breed in the estuary or the sea. In the Barwon, this group includes the Short-finned Eel, Australian Smelt, Common Jollytail and Spotted Galaxias. The Australian Grayling migrates up from the estuary to mature and breeds in freshwater with larvae returning to the estuary in the drift.

Estuarine and marine species: A large range of estuarine and marine species are found in the Barwon estuary complex although they may penetrate upstream into freshwater and can persist for some-time: Black Bream, Yellow-Eyed Mullet, Small mouthed Hardyhead, Flat-tailed Mullet and Bridled & Lagoon Goby. Whiting species and marine Gobies are also likely to be present within the estuary on a regular basis.

A large number of **exotic species** are in the Barwon Catchment and its tributaries including Eastern Gambusia, Carp and Goldfish which are distributed worldwide. Other significant exotic species, which along with Eastern Gambusia are known to be effective fish predators, are Redfin Perch, Rainbow Trout and Brown Trout are most common above Buckley's Falls. Native fish no doubt suffer significant predation pressure from exotic fish (Zaret 1980, Fletcher 1986, Lloyd 1987) when they are present. The system has a large range of exotic carp species, including Goldfish, Carp, Roach and Tench.

Each of these species have specific habitat requirements but generally they are robust and tolerate to a broad salinity range (Koehn & O'Connor 1990, Lloyd & Balla 1986, Lloyd 1987, Lloyd 2000, McDowall 1980). Black Bream and Australian Grayling have quite specific flow and salinity conditions for breeding. Blue Spot Goby is susceptible to predation and requires good vegetation to provide cover. The Mountain Galaxias is able to survive in pools over summer, provided some water remains in the pools. There are diverse habitat types within the Barwon River Catchment for native fish system and include riverine pools, riffles, runs, woody debris, undercut banks, rocks & boulders, swamps, and floodplains wetlands.

Many of these fish species will require the opportunity to migrate upstream and downstream to either complete their life-cycle or to find suitable habitats. Instream barriers such as drop-structures, road crossings, piped sections, weirs, erosion control structures, and zones of very poor habitat can all prevent fish being able to move within the system. This increases the likelihood of local extinctions of species.

In determining the environmental flow for a river system, it is important to consider its fish community and the life history of key species, together with other organisms. These key characteristics include the life span, spawning season, incubation, duration, migration, and habitat requirements.

Table 1: Freshwater fish found in the Barwon River Catchment

	Common Name	**Scientific Name**
Freshwater Native Fish	Mountain Galaxias	*Galaxias olidus*
	Common Jollytail	*Galaxias maculatus*
	Spotted Galaxias	*Galaxias truttaceus*
	Big-headed Gudgeon	*Philypnodon grandiceps*
	Blue Spot Goby	*Pseudogobius olorum*
	Congolli	*Pseudaphrits urvilli*
	Short Finned Eel	*Anguilla australis*
	Dwarf Galaxias	*Galaxiella pusilla*
	Southern Pigmy Perch	*Nannoperca australis*
	Yarra Pigmy Perch	*Edelia obscura*
	Australian Smelt	*Retropinna semoni*
	Australian Grayling	*Prototroctes maraena*
	Murray Cod*	*Maccullochella peelii peelii*
	Golden Perch*	*Macquaria ambigua*
	Macquarie Perch*	*Macquaria australasica*
	Small-mouthed Hardyhead	*Atherinosoma microstoma*
Exotic Fish	Eastern Gambusia	*Gambusia holbrooki*
	Goldfish	*Carassius auratus*
	Redfin Perch	*Perca fluviatilis*
	Brown Trout	*Salmo trutta*
	Rainbow Trout	*Oncorhynchus mykiss*
	Carp	*Cyprinus carpio*
	Roach	*Rutilus rutilus*
	Tench	*Tinca tinca*

* Translocated species, i.e., not native to the catchment

Table 2: Estuarine fish found in the Barwon River Catchment

	Common Name	Scientific Name
Estuarine Native Fish	Small-mouthed Hardyhead	*Atherinosoma microstoma*
	Black Bream	*Acanthopagrus butcheri*
	Yellow-eyed Mullet	*Aldrechetta forsteri*
	Flat-tailed Mullet	*Liza argentea*
	Bridled Goby	*Arenigobius bifrenatus*
	Lagoon goby	*Tasmanogobius lasti*
	Sea Mullet	*Mugil cephalus*
	Tamar Goby	*Afurcagobius tamarensis*
	Greenback flounder	*Rhombosolea tapirina*
	Estuary Perch	*Macquaria colonorum*
	Longsnout flounder	*Ammotretis rostratus*
	Kingfish	*Argyrosomus japonicus*
	Australian ruff	*Arripis georgianus*
	Australian salmon	*Arripis trutta*
	Luderick	*Girella tricuspidata*
	Cobbler	*Gymnapistes marmoratus*
	Sandy sprat	*Hyperlophus vittatus*
	Bluefish	*Pomatomus saltatrix*
	King George whiting	*Sillaginodes punctata*
	Smooth toadfish	*Tetractenos glaber*

3.3 Hydrology and System Operation

3.3.1 Upper Barwon

The downstream boundary of Reach 1, just upstream of Birregurra Ck, is also the boundary of the 700mm per annum rainfall isohyet. Mean rainfall at the highest elevations is around 1,400mm per year (DWR, 1989a).

The catchment of the West Barwon Dam (constructed in 1964) drains an area of 51km^2 (SKM, 2005). Immediately downstream of the dam, unimpacted mean annual discharge is 28.8GL/yr, and current mean annual discharge is 11.4GL/yr, representing a 61% reduction. The unimpacted time series has greater flows for the full range of flow duration compared to the current time series, which reflects the impact of capturing and diverting flow from the river at the West Barwon Dam to Wurdee Boluc Reservoir, which supplies Winchelsea and the Bellarine Peninsula (SKM, 2005). The current time series differ from each other for flows less than 100ML/d. The current time series is dominated by the passing flows of 5ML/d, which occur for about 70% of the time.

This reach extends down to upstream of the junction of Birregurra Creek. Although the West Barwon Dam impacts the upper part of the reach, this impact is tempered downstream by inflows from unregulated and partly regulated tributaries. There are several small tributaries (Gosling, Matthews, Callahan, Dewing and Pennyroyal Creeks) flowing from the south into the Barwon River upstream of Birregurra. Water is diverted from 3 of these into the Wurdee Boluc Inlet then sent to Wurdee Boluc Reservoir (DCNR, 1995). Boundary Creek joins the river from the north. At Rickets Marsh the catchment area is 593km2, representing a greater than 10-fold increase in area over that at West Barwon Dam. Not surprisingly, the impacts of the dam are tempered at the lower end of the reach. Unimpacted mean annual discharge is 112GL/yr, and current mean annual discharge is 101GL/yr, representing a 9% reduction. Current flows are lower than unimpacted flows across the range of flow durations by around 10-20% (although high flood flows are probably unimpacted) (SKM, 2005).

The field site at Nellie Shalley's property is located upstream of Boundary Creek junction, but downstream of East Barwon River. Thus, the hydrology of the site is not as modified as at West Barwon Dam, but further from natural than at Ricketts Marsh.

The shallow aquifer in the headwaters of the catchment is fresh (<300µS/cm), while the lower plains have a shallow aquifer that is mostly brackish (900-3000µS/cm) (DWR, 1989b).

3.3.2 Winchelsea

Mid-way along Reach 2, at Winchelsea, is the boundary of the 600mm per annum rainfall isohyet (DWR, 1989a).

The hydrology for the site is represented by the gauge at Inverleigh, located towards the downstream end of the reach. At the gauge, the catchment area is 1,269km^2, which represents an increase in catchment area from Reach 1 of 676km^2. The main tributary entering the river from Reach 1 is Birregurra Creek, which has an unmeasured catchment area. Historically flows have been increased through water transfers from the Corangamite basin via Lough Calvert Outlet during times of flood (SKM, 2005). Warrambine Creek enters the reach upstream of the lower boundary of Reach 2, and the area of this sub-catchment is also unmeasured. Historically, flows in Warrambine Creek have been increased by transfer of flows from Woady Yallock (SKM, 2005).

At Inverleigh, unimpacted mean annual discharge is 180GL/yr, and current mean annual discharge is 179GL/yr, representing a 0.4% reduction. The current hydrology of the Barwon River is not very different to the unimpacted hydrology for the low flows (<10ML/d) and med-high flows (>100ML/d). Current high flood flows may be higher than natural. However, flows 10-100ML/d, which are important because they occur for 50% of the time, have increased their percentage of time exceeded (SKM, 2005).

Much of the reach is underlain by a saline shallow aquifer (>3000µS/cm), although the downstream part of the reach is underlain by a brackish (900-3000µS/cm) shallow aquifer (DWR, 1989b). Deep saline pools occur in the middle Barwon River area as a result of groundwater intrusion near Lake Murdeduke (DCNR, 1995, p. 29).

3.3.3 Murgheboluc Valley

Rainfall in this reach averages between 500mm and 600mm per annum (DWR, 1989a).

The hydrology of this reach is represented by the gauge at Pollocksford, located mid-way along the reach. At the gauge, the catchment area is 2,713 km^2, representing an increase in catchment area from Reach 2 of 1,444km^2. The major tributary entering the Barwon River is Leigh River, with a catchment area of 881km^2 at the junction, so there is a contribution of 563km^2 drainage area from unregulated tributaries.

Unimpacted mean annual discharge is 301GL/yr, and current mean annual discharge is 291GL/yr, representing a 3.4% reduction. Flow duration curves show that the unimpacted time series is slightly greater than the current time series for high flows, however, it is below the current series for low flows (<80ML/d) due to the impact of discharges from the Ballarat South Waste Water Treatment Plant (WWTP) on the Leigh River (SKM, 2005).

Much of the reach is underlain by a saline shallow aquifer (>3000μS/cm) (DWR, 1989b).

3.3.4 Geelong

Rainfall in this reach averages between 500mm and 600mm per annum (DWR, 1989a).

The hydrology of this reach is represented by the gauge at Geelong, located towards the top end of the reach. At the gauge, the catchment area is 3,986km^2, representing an increase in catchment area from Reach 3 of 1,444km^2. The major tributary entering the Barwon River is the Moorabool River, which has a catchment area of 1,114km^2 at Batesford so there is a contribution of 330km^2 drainage area from unregulated tributaries (although part of this is the Moorabool below Batesford).

The hydrology of the Barwon River at Geelong is similar to that at Pollocksford, with a similar impact from regulation (SKM, 2005). The main difference is that flows that occur less than 20% of the time (high flows) are higher at Geelong, due to the influence of flood flows from the Moorabool River. The Moorabool River appears to have far less influence on the durations of low flows in the Barwon River.

The upper half of the reach is underlain by a saline shallow aquifer (>3000μS/cm), and the downstream half of the reach is underlain by a brackish (900-3000μS/cm) shallow aquifer (DWR, 1989b).

3.3.5 Birregurra Ck

Birregurra Creek catchment lies between the 600mm and 700mm per year mean annual rainfall isohyets (DWR, 1989a).

Birregurra Creek has an unmeasured catchment area, but it is likely to be around 80-100 km^2. Historically flows have been increased through water transfers from the Corangamite basin via Lough Calvert Outlet during times of flood (SKM, 2005). Unimpacted mean annual discharge is 3.8GL/yr, and current mean annual discharge is 19.1GL/yr, representing a 407% increase. Flow duration curves show that the current time series exceeds the unimpacted time series across the full range because of this influence (SKM, 2005).

The catchment is underlain by a saline shallow aquifer (>3000μS/cm) (DWR, 1989b).

3.3.6 Boundary Ck

Boundary Creek catchment lies in the zone above the 700mm per year mean annual rainfall isohyet (DWR, 1989a).

At the gauge the catchment drains an area of 39km^2, with the total catchment area being 51km^2 (SKM, 2005). Historically, flows in Boundary Creek have been reduced by groundwater pumping from Barwon Downs (SKM, 2005). Unimpacted mean annual discharge is 5GL/yr, and current mean annual discharge is 4GL/yr, representing a 20.6% reduction. The groundwater pumping effect is also reflected in the flow duration curves, which show that the current flow series is lower than the unimpacted flow series across the range of flows, except for the highest flows, which appear to be unimpacted (SKM, 2005).

The catchment is underlain by a fresh shallow aquifer (<300µS/cm) (DWR, 1989b). Over much of its length, Boundary Creek flows in an area in which the principal aquifers are exposed at the surface, forming a direct connection with the creek (SKM, 2002). At times of high groundwater levels the aquifers provide groundwater discharge to Boundary Creek. This discharge provides much of the summer baseflow to the Creek, although naturally it ceased to flow for about 10% of the time (SKM, 2005).

3.3.7 Upper & Mid-Leigh River

The Upper-Leigh River catchment lies in the zone above the 700mm per year mean annual rainfall isohyet. The mid-Leigh River lies in the zone between the 600mm and 700mm per year mean annual rainfall isohyets (DWR, 1989a).

Central Highlands Water operates four reservoirs in the northernmost part of the catchment to supply Ballarat and other small urban demands (SKM, 2005). These reservoirs are filled in the main by water from the Moorabool catchment. The spills from these reservoirs enter the Leigh River (SKM, 2005). The Ballarat South Waste Water Treatment Plant (WWTP) also discharges to the Leigh River (SKM, 2005).

The Upper-and Mid-Leigh River reaches are represented by the gauge at Mount Mercer, with a catchment area of 593km^2. Unimpacted mean annual discharge is 60GL/yr, and current mean annual discharge is 56GL/yr, representing a 5.7% reduction. Flow duration curves show that for high flows the unimpacted time series exceeds the current time series. However, for low flows the current time series exceeds the unimpacted time series due to discharges from the WWTP (SKM, 2005). Urban runoff processes have probably significantly altered the hydrology of the river in the zone downstream of Ballarat.

The Upper-Leigh River catchment is underlain shallow aquifers that range from fresh (<300μS/cm), marginal (300 – 900μS/cm) to brackish (900 - 3000μS/cm) (DWR, 1989b).

3.3.8 Lower-Leigh River

The Lower-Leigh River catchment (below Bamganie) is within the zone between the 500mm and 600mm per year mean annual rainfall isohyets (DWR, 1989a).

The Lower-Leigh River is represented by the gauge at Inverleigh, with a catchment area of 881 km^2, representing an increase in catchment area of 288 km^2 over that at Reach 8. The flows in the lower Leigh River are higher than those in the upper Leigh River, but the pattern of regulation impacts is similar at the two locations (SKM, 2005). Unimpacted mean annual discharge is 76GL/yr, and current mean annual discharge is 70GL/yr, representing an 8.8% reduction.

The Lower-Leigh River catchment is underlain shallow aquifers that are brackish (900 - 3000μS/cm) (DWR, 1989b).

3.4 Geomorphology

3.4.1 Upper Barwon

Catchment geomorphology

The catchment lies in the South Victorian Coastal Plains landform unit, draining the northern slopes of the Otway ranges. The catchment of the West Barwon Dam and the headwaters of the southern tributaries of the Barwon River are steep and forested, with sedimentary geology. The catchment of Boundary Ck is mostly forested although not steep, with the underlying material being coarsely- and finely-textured unconsolidated deposits (DWR, 1989a). The majority of the Upper Barwon River catchment drains a sedimentary plain (DWR, 1989a).

Channel geomorphology

The fluvial geomorphology of the river channel through this reach varies widely. In the upper part close to the West Barwon Dam the channel flows through the foothills and has a narrow floodplain confined by steep valley walls. Here the gradient is moderate, with the channel having a fine-grained bed. The channel width averages around 2-5m, with pools 0.5-1.3m deep (Tunbridge and Rogan, 2004). As the river emerges from the foothills onto the plain, the channel becomes shallow and wide, flowing through a wide partly-confined and sometimes unconfined floodplain. Toward Birregurra the channel averages 5-9m in width and with pools to 2.2m deep (Tunbridge and Rogan, 2004). Prior to European settlement most of the floodplain areas would have been swamps that were wet through the winter and spring. T here may have been multiple meandering channels through these swamps. These floodplains have since been drained, by cutting drainage channels, and by channelising the main river channel. The former channel would have had pools, perhaps separated by sandy bars (in the downstream reaches closer to Birregurra), variable width and high sinuosity. In contrast, the channelised river has a constant width and depth and is relatively straight. The bed and banks are clay-rich silty loam.

3.4.2 Winchelsea

Catchment geomorphology

About 10km upstream of Winchelsea, mid-way along this Reach, lies the boundary of the South Victorian Coastal Plain (DWR, 1989a). Downstream lies the West Victorian Volcanic Plain landform unit. Here the river flows through undulating plain topography, with finely-textured unconsolidated deposits. Most of the catchment (the upper Barwon) drains sedimentary material, but Birregurra Creek partially drains volcanic material (DWR, 1989a).

Channel geomorphology

In this reach the river has incised a narrow valley into the volcanic plain, with a narrow confined floodplain present within the valley. The bed of the river is partly bedrock controlled, although in many places it has eroded down to the underlying hard basal clay. The bed is mostly exposed hard clay, overlain in places by sandy bars, usually associated with large woody debris accumulations. In other places, outcropping basalt exerts geomorphic control on the bed. Longitudinally the river consists of fairly shallow pools and runs through shallower areas with large woody debris, and occasional steeper riffles and cascades through exposed bedrock. The width of the channel in the upper part of the reach is around 10-12m, with pools 1.5-2.3m deep (Tunbridge and Rogan, 2004). Between Winchelsea and Inverleigh the river has some extensive pools. Here the width of the channel is around 17-25m and pool depth is up to 4.7m (Tunbridge and Rogan, 2004). Gravel may be present in some riffles (Tunbridge and Rogan, 2004).

Deep saline pools occur in the middle Barwon River area as a result of groundwater intrusion near Lake Murdeduke (DCNR, 1995, p. 29).

3.4.3 Murgheboluc Valley

Catchment geomorphology

This reach is located within the West Victorian Volcanic Plain landform unit (DWR, 1989a). Here the river flows through undulating plain topography, with finely-textured unconsolidated deposits. The river receives major inputs from the northern Leigh River tributary, which also drains mostly volcanic rocks. At the lower end of the reach, on the southern side of the river is a hilly area of sedimentary rocks (DWR, 1989a).

Channel geomorphology

In this reach the river has incised a narrow valley into the volcanic plain, with a narrow confined floodplain present within the valley. Through Murgheboluc the bed of the river is partly bedrock controlled. In this upper part of the reach, down to Ceres, the bed material is coarse, varying from cobbles/boulders to coarse sand. The channel morphology is large deep pools, coarse steep riffles, islands, and steeply sloping banks.

Buckley's Falls is a major bedrock outcrop located at the end of the reach, just above where the Moorabool River joins the Barwon River. Balm's Weir has been constructed 400m upstream of the Falls. The river between these features is a deep pool, under the hydraulic influence of the Falls (Tunbridge and Rogan, 2004). For a distance upstream of the Weir the Barwon River is under the hydraulic influence of the Weir, forming a pool environment. Upstream to Ceres the river has extensive pools in the flat, meandering channel (Tunbridge and Rogan, 2004), with cutoff channels present on the floodplain.

3.4.4 Geelong

Catchment geomorphology

This reach is located within the West Victorian Volcanic Plain landform unit. Here the river flows through undulating plain topography, with finely-textured unconsolidated deposits (DWR, 1989a).

Channel geomorphology

The channel has incised a narrow valley into the volcanic plain, with a narrow confined floodplain present within the valley. This is an 18km long reach of low sinuosity. The morphology is pools 4-6m deep in a channel up to 59m wide (Tunbridge and Rogan, 2004). Substrate is silt and clay (Tunbridge and Rogan, 2004).

3.4.5 Birregurra Ck

Catchment geomorphology

The majority (the northern) part of the Birregurra Ck catchment drains the West Victorian Volcanic Plain landform unit (DWR, 1989a). Here the creek flows through undulating plain topography, with finely-textured unconsolidated deposits. The southern part of the catchment drains finely-textured sedimentary material (DWR, 1989a).

Channel geomorphology

The creek has incised through the volcanic material to form a narrow and low gradient, partly confined channel. The floodplain alternates between a wide floodplain (about 100 – 150m wide) and narrow constricted areas (about 10-20m wide). The bed is composed of clay-rich silty material and lacks substantial pools.

3.4.6 Boundary Ck

Catchment geomorphology

The catchment of Boundary Ck is mostly forested although not steep, with the underlying material being coarsely- and finely-textured unconsolidated sedimentary material (DWR, 1989a).

Channel geomorphology

The lower part of the creek has a relatively narrow flooplain (20 – 50m wide), with an unconfined channel. The channel appears to be channelised and incised. The channel has a pool/run/riffle appearance, but the pools are formed by organic matts that form hydraulic controls. The pools are deep with a hard clay bed and the shallower areas are narrower and organic, formed by macrophytes and grasses that have confined the channel. The organic matted bed contains fine red sediment (clay and fine silt), with the likely origin being forestry roads and other local unsealed roads. The local bank material of Boundary Creek is black soil.

3.4.7 Upper- and Mid-Leigh River

Catchment geomorphology

The Upper-Leigh River drains gentle to moderately sloping dissected tablelands. The underlying geology is mostly sedimentary rocks, with granites and gneisses forming low hills. This area falls within the dissected uplands geomorphic unit of the Central Victorian Uplands region (DWR, 1989a).

A small section at the top of the catchment near Ballarat, and also where the first order headwater streams are located, drains volcanic rocks (DWR, 1989a).

Extensive gold mining occurred within the upper part of the Leigh River catchment since gold was discovered in 1851. Mining impacts influenced the river in two ways

(Earth Tech, 2004). Firstly, alluvial mining literally turned over large areas of valley floor of the Leigh River between Ballarat and Garibaldi. Floodplain deposits were removed in order to access gold bearing gravels. Secondly, mining on the valley hillsides removed large volumes of rock. The silt and sand fractions would have been washed from the tailings left on the floodplain and transported into the Leigh River (Earth Tech, 2004).

The Upper-Leigh River reach from Ballarat to Napoleons is partly confined, with extensive erosion of the gravel, silt and sandy banks (Earth Tech, 2004). Some cut and fill sub-catchment streams are located to the north west of the Upper-Leigh River catchment (west of the Yarrowee in the area of Dog Trap and Winter Creeks). Where gullied these sub-catchments form secondary sources of sediment to the Leigh River (Earth Tech, 2004).

The Mid-Leigh River reach lies within the West Victorian Volcanic Plain landform unit. Here the river flows through undulating plain topography, with finely-textured unconsolidated deposits. The Mid-Leigh River, from Grenville to Willangi is a gorge. This is a high energy sediment transport zone that also contains sediment stores in bars and benches (Earth Tech, 2004).

Channel geomorphology

The headwater zone of the Leigh River is largely in the Ballarat urban area. Streams are bedrock confined, or have been in some cases completely rock armoured (Earth Tech, 2004). Through the gorge the river has a narrow valley floor with localised sediment accumulation occurring in the form of gravel and cobble bars or benches. Stream power during flood events would be high. Longitudinally the river contains pools of varying depth and length separated by bedrock-controlled rapids and cascades (containing boulders and cobbles).

3.4.8 Lower-Leigh River

Catchment geomorphology

The Lower-Leigh River reach lies within the West Victorian Volcanic Plain landform unit. Here the river flows through undulating plain topography, with finely-textured unconsolidated deposits (DWR, 1989a).

Just north of Shelford the valley widens to around 1.0 - 1.5km in width (Earth Tech, 2004), forming the lower-Leigh River reach.

Channel geomorphology

From Shelford, floodplains extend laterally for several kilometres down each side of the moderately sinuous channel (Earth Tech, 2004). The banks of the river are sandy, and the channel bed south of Shelford is homogenous and flat except at tight bends where scour occurs (Earth Tech, 2004). The sand deposits appear to be less extensive downstream, where the channel long profile is controlled by large woody debris accumulations. Sand bars have developed around the woody debris and shallow pools are formed in-between these constrictions.

3.5 Barwon Estuary Complex

The Barwon River estuary is that part of the river system affected by tidal influence and with a salinity gradient from the dilution of sea water from freshwater flows. The original estuary, prior to European settlement, extended upstream past Geelong. A breakwater was bult just south of Geelong in 1844 to enable a water supply and water level through Geelong. Around 1898 a second breakwater (the "Lower Breakwater") was built at the south-east of Reedy Lake (and upgraded in the 1950s) to further limit the upstream extent of saline water. These breakwaters have changed the nature of the Estuary with now significant parts of the system not have access to the estuarine or marine waters but relying on freshwater from the catchment (Sherwood *et al.* 1988).

The estuary system is now an estuary complex which consists of several distinct spatial and ecological components (see Figure 3):

- Lake Connewarre
- Salt Swamp
- Lower Barwon
- Reedy Lake
- Hospital Swamp

Lake Connewarre, Salt Swamp and the Lower Barwon are still estuarine but Reedy Lake and Hospital Swamp are now freshwater systems. These systems have been listed as an internationally significant, Ramsar listed, wetland because of its diverse and large waterbird, fish and aquatic vegetation communities (Sherwood *et al.* 1988).

Lake Connewarre is a large shallow (average depth 0.1m) estuarine lagoon in the lower reaches of the Barwon River. Sedimentation from the Barwon River has resulted in a silty-clay substrate. Salt Swamp is a relatively small reed swamp which is inundated by spring tides, off Lake Connewarre. The Lower Barwon is a river channel habitat Reedy Lakes and Hospital Swamps are a mosaic of reed beds, aquatic macrophyte beds and open water, now dependant upon manipulated flows (PPK 2000) from the Barwon River above the lower breakwater (Sherwood *et al.* 1988).

The current aim of management (and that proposed in this study) is to sustain the current complex of freshwater and estuarine habitats rather than return the system to completely estuarine system originally present (Sherwood *et al.* 1988, Sherwood pers comm. 2005).

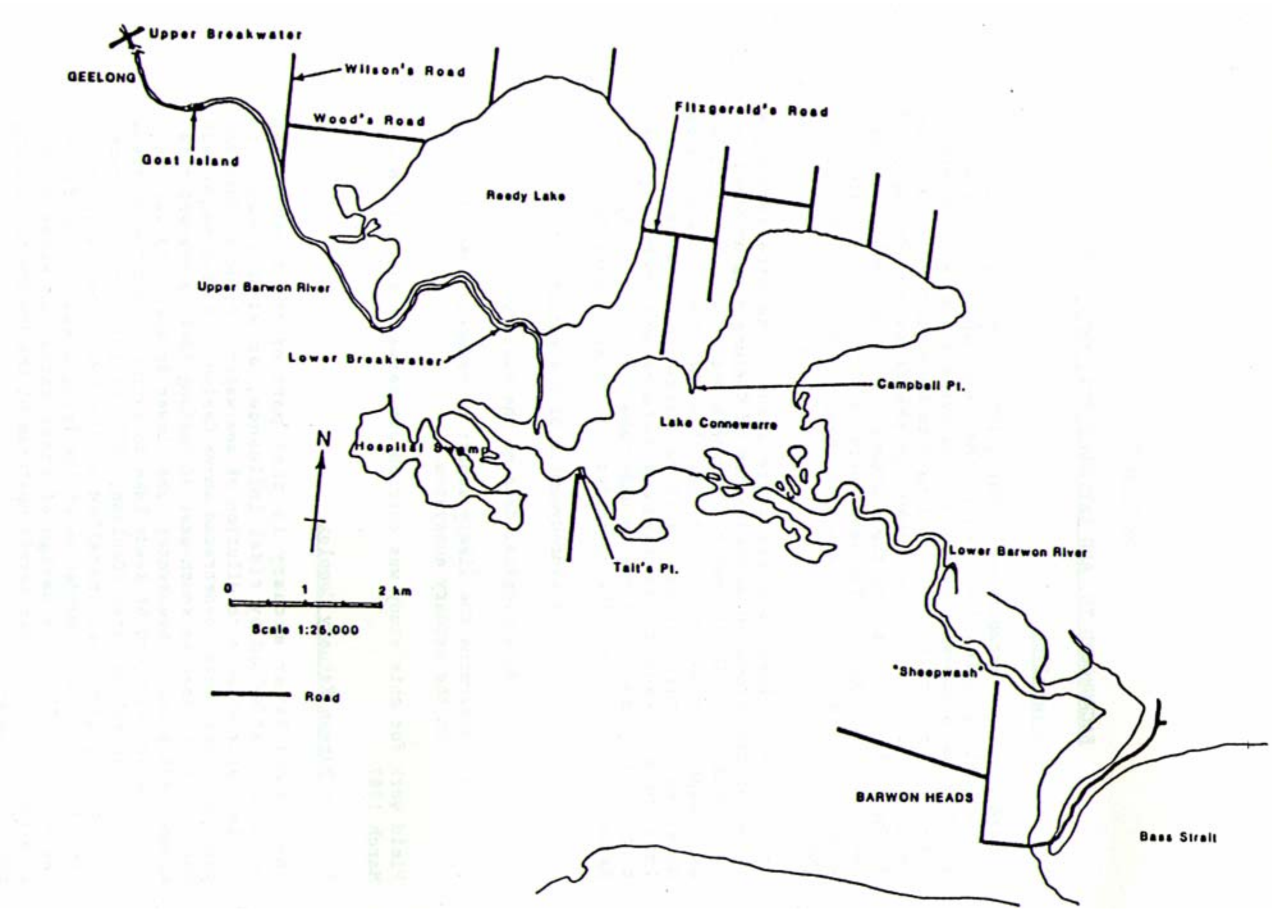

Figure 3: Barwon Estuary Complex

The estuarine wetland system has extensive and well preserved native plant communities.

The vegetation of Lake Connewarre is strongly influenced by the water level and salinity regime. The tidal amplitude is limited to 0.15 m. The lake is efficiently flushed by tides, with a residence time of less than 2 weeks. The salinity normally varies from fresh to close to that of sea water, but can become hypersaline during prolonged periods of low flow.

Lake Connewarre has open water with isolated occurrences of *Ruppia maritima* and *Zostera marina*. The lack of aquatic plants has been attributed to turbulence, turbidity and nitrogen limitation.

The vegetation of the reverse surrounding Lake Connewarree is high diverse. Forty five of the 53 salt marsh species that occur in Victoria are present in the reserve. It is the largest area of native vegetation remaining on the Bellarine Peninsula. Lake Connnewarre marks the southern-most occurrence of *Halosarcia halocnemoides* and *Muehlenbeckia florulenta* and the western most occurrence of *Avicennia marina.* The reserve supports the most *Wilsonia humilis* herbland and the most extensive *Distichlis disticophylla* grassland in the state.

Reedy Lake is a freshwater lake that is maintained at an artificially high level by regulators. Freshwater enters the lake via two channels from the Barwon River and the lake level responds to changes in river discharge. Any tidal influence in the lake or in the river upstream is prevented by barrages downstream of the lake. The salinity of the lake remains 1500 to 3000 EC units more saline than the river due to its restricted circulation and evaporation. The available documents do not describe the depth range of the lake (PPK 2000).

Reedy Lake has extensive stands of emergent and submerged plants dominated by *Phragmites australis* and *Typha orientalis*. Other aquatic plants include the submerged and floating species *Crassula helmsii, Azolla filiculoides, Lemna minor* and *Wolffia australiana*. There are areas of open water in which patches of *Schoenoplectus validus* and *Eleocharis sphacelata* occur. Submerged aquatic plant communtieis are diverse and include *Myriophyllum* spp. (3 species), *Potamogeton* spp. (2 species), *Lepilaena* spp. (2 species), *Ranunculs trichophyllus, Ruppia maritima* and *Vallisneria gigantea* (Yugovic 1985 cited in DCNR 1995).

Salt Swamp has unique vegetation associations. The southern part of Salt Swamp is characterised by prolonged inundation by brackish water following major floods of the Barwon that alternate with dry periods in summer and autumn. The swamp does not come under tidal influence. When dry, a *Wilsonia humilis* herbland develops on the swamp bed. When flooded, the swamp suupports the growth of the aquatic plants *Ruppia maritima, Lepilaena preissii* and *Chara* sp. The *Wilsonia humilis* herbland and possibly the *Distichlis disticophylla* grassland of the reserve are maintained by the swamp annually achieving a depth sufficient to inundate these areas.

Reserve has anumber of weed species. Annual herbs and grasses such as *Polypogon monspeliensis, Critesion marinum, Atriplex prostrata, Sonchus oleraceus and Rumex cripsus* are widespread and common in relatively elevated areas. *Parapholis incurva* is a particular problem at Murtnaghurt Swamp. *Cortaderia selloana* has invaded the samphire herbland.

Noxious weeds recorded in the reserve includee *Chryanthemoides monilifera, Cirsium vulgare, Foeniculum vulgare, Foeniculum vulgare, Homeria minata, Lycium ferocissimum, Marrubium vulgare, Oxalis pes-caprae* and *Watsonia meriana*.

It has been previously concluded that summer flows at Geelong should not fall below 30 ML/d, but can be less during periods of naturally low flow. Flows below this level are likely to make Lake Connewarre hypersaline. Although this occurred naturally, prolonged or regular hypersaline periods will change the ecological character of the estuary (Sherwood *et al.* 1988).

Winter spring flows of more than 600 ML/d are required to keep the lake fresh. Higher flows again are required to inundate the wetlands associated with Lake Connewarre (Sherwood *et al.* 1988).

4. FLOW DEPENDENT ASSETS

Flow dependent assets of the study area that can be identified from the available information are:

- ☐ High aquatic biodiversity with high numbers of species of fish, aquatic invertebrates and aquatic and riparian vegetation;
- ☐ Three Victorian rare and threatened listed fish species - Dwarf Galaxias, Australian Grayling & Yarra Pigmy Perch. Australian grayling are also listed nationally under the EPBC Act;
- ☐ Intact riparian vegetation communities in the Leigh River Gorge, and in particular their continuous linkage to terrestrial vegetation remnants;
- ☐ River Red Gum on the Leigh River below the Leigh River Gorge and on the Barwon River;
- ☐ Shrubby vegetation assemblages on the Barwon River, comprised of species such as *Hymenanthera dentata, Leptospermum* sp. and *Callistemon seiberi*;
- ☐ Emergent macrophyte assemblages on the Barwon River, comprises of species such as *Bolboschoenus medianus, Phragmites australis* and *Poa labillardieri*.
- ☐ 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;
- ☐ Salt marsh communities fringing Lake Connewarre; and,
- ☐ ISC assessment shows the flow regime is in mostly good or excellent condition with some notable exceptions (Upper Barwon and the downstream of the Moorabool River).

5. REACH AND SITE SELECTION

The initial reach delineation and Scientific Panel Assessment sites was evaluated using:

- ☐ Information reviewed in Section 3 above;
- ☐ An initial site visit by the CMA project manager and the Consultant's; and,
- ☐ Fine tuning by the Scientific Panel during their field assessment.

This resulted in the following reach and site delineation shown below:

Reach Name	Description	Site
1. Upper Barwon	Barwon River from West Barwon Reservoir to Birregurra Creek Confluence	Upstream of Boundary Creek confluence
2. Winchelsea	Barwon River from Birregurra Creek Confluence to Leigh River confluence	Kildean Road Public Reserve
3. Murgheboluc Valley	Barwon River from Leigh River confluence to Moorabool River Confluence	Murgeboluc
4. Geelong	Barwon River from Moorabool River Confluence To Lower Breakwater	King Lloyd Park
5. Estuary	Lower Breakwater, Lake Connewarre and Reedy Lake, lower estuary to Barwon Mouth	Several subsites
6. Birregurra Ck	Birregurra Creek	McDonnells Rd
7. Boundary Ck	Boundary Creek	Upstream of Barwon Confluence
8. Mid Leigh River	Leigh River from Napoleons Rd to Quiney Hill	Downstream of Mt Mercer Gauge Station
9. Lower Leigh River	Leigh River from Quiney Hill to Barwon confluence	Upstream of Shelford

Figure 3 shows this reach delineation and the site locations within the Barwon River catchment.

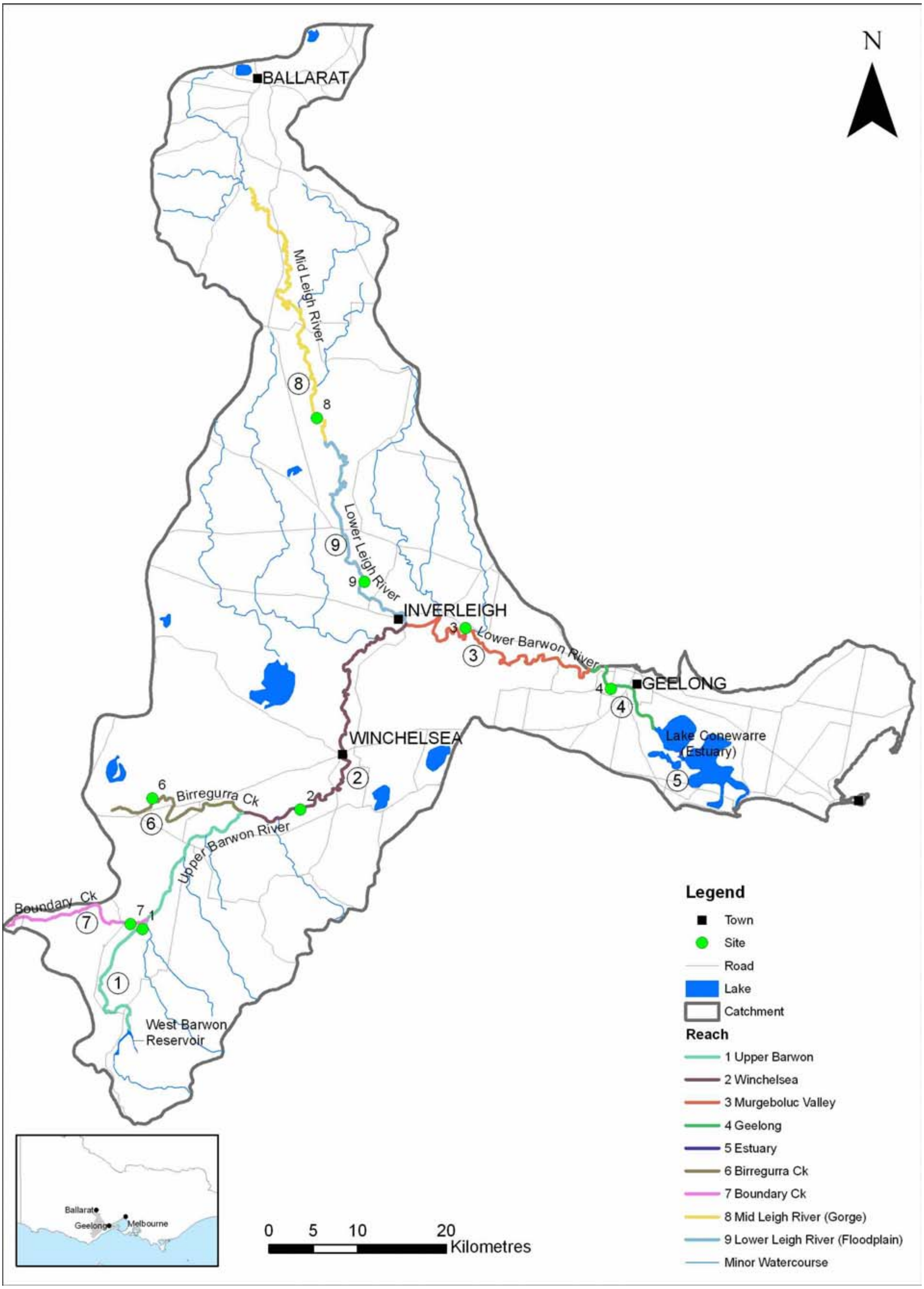

Figure 4: The reaches and sites selected for the Barwon Environmental Flow Determination Project

Reach **1. Upper Barwon**	
Reach Description	Barwon River from West Barwon Reservoir to Birregurra Creek Confluence
Site Name	1. Boundary Creek
Site Description	Upstream of Boundary Creek confluence on Nellie Shalley's property
Map Reference	E 738673 N 5743191

Reach **2. Winchelsea**	
Reach Description	Barwon River from Birregurra Creek Confluence to Leigh River confluence
Site Name	2. Kildean Road
Site Description	Public Reserve – adjacent to Shirley Leake's Property
Map Reference	E 756682 N 5756754

Reach **3. Murgheboluc Valley**	
Reach Description	Barwon River from Leigh River confluence to Moorabool River Confluence
Site Name	3. Murgeboluc
Site Description	David Cotsell's Property
Map Reference	E 249152 N 5778003

Reach **4. Geelong**	
Reach Description	Barwon River from Moorabool River Confluence To Lower Breakwater
Site Name	4. King Lloyd Park
Site Description	Shannon Ave to Queens Park Road, Geelong
Map Reference	

Reach **5. Estuary Complex**	
Reach Description	Lower Breakwater, Lake Connewarre and Reedy Lake, lower estuary to Barwon Mouth
Site Name	5. Estuary Complex
Site Description	Several Subsites at Lake Connewarre, Reedy Lake, Hospital Swamps, Salt Swamp and Lower Barwon
Map Reference	

Reach **6. Birregurra Ck**	
Reach Description	Birregurra Creek – a tributary of the Barwon River, draining the catchment to the west of the Barwon.
Site Name	6. Birregurra Creek
Site Description	At McDonnells Rd, James Dennis' Property
Map Reference	E 740466 N 5757952

Reach **7. Boundary Ck**	
Reach Description	Boundary Creek – a tributary of the Barwon River, draining the catchment to the west of the Barwon
Site Name	7. Boundary Creek
Site Description	Nellie Shalley's property
Map Reference	E 737476 N 5743861

Reach **8. Mid Leigh River**	
Reach Description	Leigh River from Napoleons Rd to Quiney Hill
Site Name	8. Downstream of Mt Mercer Gauge Station
Site Description	Downstream of Mt Mercer Gauge Station at Wilma Webb's Property
Map Reference	E 758872 N 5801085

Reach **9. Lower Leigh River**	
Reach Description	Leigh River from Quiney Hill to Barwon confluence
Site Name	9. Upstream of Shelford
Site Description	Garry Wishart's Property
Map Reference	E 237546 N 5782459

6. CONCLUSION

This Site Paper will be followed by several important steps which will lead to the development of the **Issues Paper**. The Scientific Panel will assess each reach at the selected sites during a field inspection and subsequent investigations of flow regimes and ecological requirements. A detailed topographic survey will be undertaken following the field work (which has located several cross-sections at each site) and this information incorporated into a hydraulic model for each site. This model will be used to further investigate the flow related issues and changes since regulation and catchment development. It will be an important tool for the Scientific Panel to further develop flow objectives for the Barwon.

The Issues Paper will allow the further development of the issues identified in this report by documenting the key flow related issues of the Barwon system, the management objectives for key ecological values and preliminary flow objectives for the ecological and geomorphological components of the system.

Following these steps, the Scientific Panel will conduct a workshop to develop flow recommendations for each reach to meet their agreed environmental objectives. In this step, the Scientific Panel will need to consider, changes to flow regime affecting aquatic biota, groundwater extraction impacts on GDEs (Groundwater Dependent Ecosystems), barriers to fish migration (there are 7 species which are migratory); and, sedimentation in streams and wetlands. These issues will be evaluated in the Issues Paper.

7. REFERENCES

Craigie and Associates. (1990). Ballarat Water Board River Management Study - Final Report on Restoration. Report prepared by N.M. Craigie and Associates and Biosis Research for the Ballarat Water Board, Victoria.

DCNR. (1995). Barwon River Basin Overview Report – Environmental input into the bulk entitlement conversion process. Department of Conservation and Natural Resources, Victoria.

DWR . (1989a). Water Victoria, an Environmental Handbook. Department of Water Resources, State of Victoria, Melbourne.

DWR. (1989b). Water Victoria, a Resource Handbook. Department of Water Resources, State of Victoria, Melbourne.

Earth Tech. (2004). Leigh River sediment sourcing and transport. Corangamite Catchment Management Authority.

Fletcher, A. (1986). Effects of introduced fish in Australia. In DeDecker, P. and Williams, W.D. Limnology in Australia. CSIRO Publishing.

Kinhill Stearns. (1986). Enlargement of Wurdee Boluc Reservoir. Environmental Effects Statement July 1986. Geelong and District Water Board.

Koehn, J.D. & O'Connor, W.G. (1990). Biological information for Management of Native Freshwater Fish in Victoria. Dept of Conservation & Environment.

Lloyd L.N. & S.A. Balla. (1986). Wetlands and Water Resources of South Australia. Dept. of the Envt & Planning, S.A.

Lloyd, L.N. (1987). Ecology and distribution of the small native fish of the lower River Murray, South Australia and their interactions with the exotic mosquitofish, *Gambusia affinis holbrooki* (Girard). M.Sc. Thesis, Dept. of Zoology, University of Adelaide.

Lloyd, L.N. (2000). The Environmental Water Requirements & Ecology of the Broughton River, S.A. Report to the SA Report to the SA Dept for Environment, Heritage and Aboriginal Affairs.

McDowall, R.M. (1980). Freshwater Fishes of SE Australia. Reed, Sydney.

Merrick, J.R. & Schmida G. (1984). Australian Freshwater Fishes: Biology and Management. Griffin Press, Netley SA.

Mitchell, P. (1990). Environmental Condition of Victorian Streams. Department of Water Resources, Victoira.

NRE. (2002). FLOWS – a method for determining environmental water requirements in Victoria, Department of Natural Resources and Environment, Victoria.

PPK (2000). Reedy Lake Geelong. Draft Water Level Management Plan. PPK Report to Parks Victoria

Sherwood, J.E. B.D. Mitchell, C.J. Magilton, C.J. Walsh & G.M. Newton. (1988). A study of the Barwon Estuary Complex Technical Report. Report to the Department of Water Resources Victoria.

SKM. (2002). Barwon Downs Groundwater Study Stage 2. Impacts on Boundary Creek. Barwon Region Water Authority, February.

SKM. (2005). Environmental Water Requirements of the Barwon System. Preparation of Daily Streamflow Data for the Barwon River, Draft A. Report to Corangamite Catchment Management Authority, May.

Tunbridge, B.R. 1988. Environmental flows and fish populations of waters in the South Western Region of Victoria. ARI Report DCF&L

Tunbridge, B.R. and Rogan, P.L. (2004). A Guide to the Inland Angling Waters of Victoria. 5th Edition. Department of Primary Industries, The State of Victoria. URL: http://www.dpi.vic.gov.au/angling/33-Barwon/Basin%20TEMPLATE%20Waters.htm (accessed 1st July 2005).

Yugovic, J. (1985). The vegetation of the Lake Connewarre State Game Reserve. Arthur Rylah Institute for Environmental Research Technical Report Series 18. Department of Conservation Forests and Lands, Victoria.

Zaret, T.M. (1980). Predation and Freshwater Communities. Yale University Press, New Haven, USA.