Understanding the environmental water requirements of the Gippsland Lakes system

Scoping Study

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Cover photo
Confluence of the Perry River, Avon River and Lake Wellington, and fringing wetlands.
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Summary

Background

This scoping study is the first stage of a project to determine the environmental water requirements of the Gippsland Lakes system. The need to understand the environmental water requirements of the lakes system and the ecological impact of further water extractions from their catchments was identified in the Victorian Government’s *Our Water Our Future* policy document (DSE 2004).

The scoping study set out to:

- summarise what is currently known and not known about the ecological role of freshwater inflows to the Gippsland Lakes, their fringing wetlands and the estuarine reaches of their inflowing rivers
- refine the geographic scope of an investigation into the system’s environmental water requirements and
- develop an approach for the determination of the environmental water requirements of the Gippsland Lakes system.

The main findings

The main findings of the scoping study are presented below.

Values

The Gippsland Lakes system has high regional, national and international conservation value and is listed as a Wetland of International Significance under the Ramsar Convention. Its variety of physical habitats supports an abundance and diversity of vegetation, waterbirds and fish.

The system provides direct economic benefit via commercial fishery and tourism. It provides visual amenity and recreational opportunity for boating, swimming, bird watching, nature walking, camping and sightseeing.

Ecology

The Gippsland Lakes system is a complex, spatially diverse estuarine environment with a variety of physical habitats in the deep and shallow lakes, fringing wetlands and estuarine reaches of inflowing rivers and creeks. The condition of the system, including water quality and the state of its vegetation, fish and waterbird populations, is closely linked to its economic, social and environmental values.

Hydrology

The Gippsland Lakes system consists of numerous inter-connected water bodies. Each water body receives freshwater inflows directly or indirectly from one or more waterways.

The Latrobe River catchment in the west contributes 44% of mean annual inflow to the lakes, and the Mitchell River catchment in the east contributes 35%. These are the biggest contributors of freshwater inflow.
to the lakes system.

On average, nearly 20% of natural stream flows to the lakes are extracted upstream. Most extraction is from the Latrobe system where 33% of stream flow is extracted. Worst case climate change may account for another 34% decrease in stream flow to the lakes (based on original inflows).

The permanent entrance to the sea creates the broad pattern of spatial variability in salinity across the lakes system. Freshwater inflows are principally responsible for temporal variation in salinity and water regimes.

**Hydrology-ecology linkages**

The ecological condition of the lakes system is strongly linked to its freshwater inflow regime. The variability of salinity in space and time results in a wide diversity of habitats, which along with the size of the system, underpin the unique character and ecological significance of the Gippsland Lakes.

Relationships between key ecological values and the magnitude, duration, frequency, timing and quality of freshwater inflows are qualitatively described using local and international application of general ecological principles. Some quantified estimates of ecologically important local flow thresholds are proposed.

Seasonal flow pulses below river bank height are necessary for fish breeding and migration in the estuarine river reaches and the main lakes. Overbank flows which inundate and flush the fringing wetlands help to sustain and rejuvenate these areas respectively. The volume of inflows to the main lakes over longer time periods (months and years) determines their background salinity regime, and hence the types of biota that will inhabit the lakes.

**State of existing knowledge**

In general, physical responses can be predicted, whereas ecological responses are poorly understood. We can go some way toward understanding the trajectory of current ecological condition. Our ability to set realistic management objectives based on likely ecological response to future hydrologic change is limited – mainly by a restricted understanding of the biological functioning of the system. It is possible however, to use the assembled knowledge to direct future investigations and to establish spatial priorities for the determination of environmental water requirements.

**Impact of hydrological changes**

The combination of decreased inflows and the permanent entrance to the sea has resulted in increased salinities throughout the lakes system, transforming it from a freshwater-brackish system to an estuarine one. These changes continue to impact on:

- vegetation in fringing wetlands and riparian zones
- submerged aquatic plants in the main lakes and fringing wetlands
- fish and bird populations and
- water-column stratification in the main lakes, with implications for the incidence and severity of noxious algal blooms.

The likely future state of the system under worst case climate change, in addition to continuing water extraction, is predominantly marine, with a retreat of the estuarine habitats to the margins of the system i.e. the fringing wetlands and lower river reaches.

### Priorities for determining environmental water requirements

Spatial components of the system have been assigned priorities based on the relative sensitivity of parts of the lakes system to hydrologic change, their relative importance to the values of the lakes system, and our ability to influence crucial flow components. Freshwater and variably saline fringing wetlands are the highest priority components, followed by the estuarine reaches of the inflowing rivers and Jones Bay (see figure below).

The challenges posed by climate change and an increasing demand for water resources justify understanding the environmental water requirements of the Gippsland Lakes system. Freshwater inflows will play an important role in the future of the lakes system regardless of whether the long-term management objectives are to protect existing values or to manage a transition to a new more saline state.

### Approach to determining environmental water requirements

The recommended approach recognises that decisions about environmental water "requirements" are inexorably linked to management decisions about condition targets; and condition targets will themselves be informed by impacts on economic, social and environmental values. The approach allows preliminary management decisions to be proposed on the basis of available knowledge, using those decisions to target knowledge gaps and in turn to test and refine the decisions.

The proposed approach is:

- **iterative**: recognising that initial management decisions demarcate areas of knowledge to be developed, and once developed, the knowledge allows decisions to be tested and refined
- **targeted**: knowledge is built to reduce key areas of uncertainty by specifically addressing priority knowledge gaps and
- **progressive**: short term answers evolve and are refined through time in response to emerging priorities and improving knowledge

The approach can be used to provide short term input to a review of the interim water use caps during the development of the Gippsland Region Sustainable Water Strategy.

In the absence of specific water development pressures, there is justification to maintain the existing water use caps on the catchments of the Gippsland Lakes given the very high values of the lakes system and their demonstrated reliance on freshwater inflows.
Schematic diagram showing the relative priority of the mega-habitats of the Gippsland Lakes system for the determination of environmental water requirements.
1 Introduction

1.1 Background

The work reported here is the scoping phase of an investigation of environmental water requirements for the Gippsland Lakes system (see Map 1). The Gippsland Lakes system includes Lakes Wellington, Victoria and King, their fringing wetlands and the estuarine reaches of the inflowing rivers. The eventual goal of the whole investigation is to determine the environmental water requirements of the Gippsland Lakes ecosystems, and assess the adequacy of the Environmental Water Reserve for the Gippsland Lakes.

In 2004, the Victorian Government instituted a program of policy reforms to facilitate sustainable use of water resources across the state. This program included establishment of Environmental Water Reserves (EWR) for all river systems. EWRs for the catchments of the Gippsland Lakes were set by capping consumption at current levels in all Gippsland Lakes catchments except for an allowance of 2,000 ML for possible new development in the Nicholson, Tambo, Mitchell and Avon River catchments. The government recognised the interim nature of these water use caps, and stated that:

“... the size of the Environmental Water Reserve needed to ensure the health of the Gippsland Lakes as a whole needs to be confirmed.

The Government will undertake an assessment to determine the impact of further river extractions on the Gippsland Lakes” (DSE 2004).

This scoping study is the first stage of that work.
The scoping study has assessed how to achieve this goal by:

- reporting on the existing state of knowledge about the relationship between freshwater inflows and the ecology of the lakes system
- reporting on the gaps in knowledge and understanding that need to be filled before an adequate, scientific understanding of the system’s flow requirements can be developed
- allocating spatial priorities for this work
- recommending an approach to determining the environmental water requirements of the lakes system
- assessing the suitability of this approach.

This scoping study report is based on a more detailed Technical Report which is available separately from the East and West Gippsland Catchment Management Authorities (Ecos Consortium 2009).

### Environmental water requirements and reserves

The true environmental water requirement of any ecosystem is its natural inflow regime. Any departure from this regime results in some level of ecological risk, degradation and/or change. For water allocation and management purposes, an environmental water requirement is the flow regime needed to sustain the ecological values of a water-dependent ecosystem at a low level of risk.

The Environmental Water Reserve (EWR) is the share of water resources set aside to maintain the environmental values of a water system and other water services which are dependent on the environmental condition of the ecosystem. Due to necessary trade-offs between consumptive, social and environmental demands, scientifically determined environmental water requirements are often not met by the EWR.

### 1.2 Structure of this report

This scoping study report contains the following sections.

- **Section 1** This introduction
- **Section 2** A compilation and interpretation of existing information on the physical and ecological attributes of the Gippsland Lakes system and related social and economic values.
- **Section 3** The existing state of knowledge about the relationship between hydrologic inputs and ecological responses, indicative quantified flow thresholds and inferences and a discussion about the gaps in existing knowledge.
- **Section 4** The likely consequences of reduced freshwater inflows now and in the future, and the spatial priorities for determining environmental water requirements for the lakes system.
- **Section 5** An approach to determining the environmental water requirements of the lakes system.
2 Ecological and physical characteristics of the Gippsland Lakes system

2.1 Overview

The Gippsland Lakes system is a large estuarine complex located on Victoria’s south-east coast and linked to the Southern Ocean by an artificially maintained channel at Lakes Entrance (Map 1). The system consists of a series of large coastal lagoons (known locally as lakes) formed behind a coastal barrier dune system and surrounded by numerous fringing wetlands. Seven major rivers, some regulated and others unregulated, flow into the lakes from catchments that vary widely in land use (Map 2).

![Map 2 Gippsland Lakes catchment](image)

2.2 Ecological values

The Gippsland Lakes system is an estuary of high regional, national and international conservation value. It is listed as a Wetland of International Significance under the Ramsar Convention.

Estuaries are environments where fresh water mixes with seawater. Almost all of the Gippsland Lakes system is an estuarine environment, meaning that its ecological functions are controlled by the mixing of seawater and fresh water and characterised by a spatially and temporally variable salinity regime. Some parts, near the entrance, are nearly oceanic...
and other parts, on the main rivers, may be dominated by fresh water. The mixing of freshwater and seawater creates the unique character of the Gippsland Lakes system. While the entrance is very significant in creating the broad pattern of spatial variability in salinity across the system, its artificial permanence means that it is the variability in freshwater inflows that are now principally responsible for temporal variation in salinity and water regimes. This variability in space and time results in a wide diversity of habitat types, which along with the size of the system, underpin the diversity of habitats and the overall ecological significance of the Gippsland Lakes.

Physical habitats

The Gippsland Lakes system supports a wide range of habitats, including planktonic systems in the water column of the main lakes and rivers, submerged and emergent macrophytes, extensive zones of freshwater-salt water interface, exposed and submerged sediments, and fringing riparian zones dominated by vegetation such as rushes, reeds and sedges.

Key habitats of the main lakes include seagrass beds, sandy and muddy benthic sediments, fringing reed beds, open water (deep) and shallow littoral fringes. Each of these habitats supports a diverse ecological food web ranging from benthic algae to fishing birds and dolphins. Extensive fringing wetlands have developed along the margins of the inflowing rivers adjacent to the main lakes. Vegetation communities vary due to each wetland’s elevation on the floodplain, salinity levels, proximity to the river or estuary and resultant frequency and duration of inundation.

A notable attribute of many wetlands are the extensive Swamp Scrub-dominated vegetation communities, and abundant waterbird populations. Where conditions are drier and more saline, extensive saltmarsh communities have developed. The low gradient of the inflowing rivers also means that estuarine conditions extend many kilometres upstream, providing desirable habitat for estuarine fish and invertebrate species. Iconic wildlife that are supported by the diverse habitats and valued by the community include waterbirds and fish.

Waterbirds

In large part, the high conservation value of the Gippsland Lakes results from the diversity and size of the range of different habitats that occur in the system. The Gippsland Lakes ecosystems support diverse and large waterbird populations, which make use of the main lakes, the fringing wetlands and the estuarine reaches of the inflowing rivers. The species diversity and abundance of waterbirds, however, is concentrated at lake margins and in fringing wetlands.

Important sites include:

- the Roseneath Peninsula wetlands between Lakes Wellington and Victoria (such as Victoria Lagoon and Morley Swamp)
- Macleod Morass and the western end of the Mitchell River silt jetties near Bairnsdale
- Sale Common, Dowd Morass and Heart Morass along the lower Latrobe River floodplain
- Jones Bay and Bosses Swamp at the northern end of Lake King
- Reeve Channel near Lakes Entrance
- shorelines of the Gippsland Coastal Park including Lake Reeve and the Bunga Arm along the outer coastal barrier.

Many waterbird species that regularly migrate between Japan or China and south-east Australia (such as sandpipers, snipe and terns) utilise the lakes and their fringing wetlands during the southern hemisphere summer. The habitats of these species in all three countries are protected under the Japan–Australia and China–Australia Migratory Bird Agreements.

There are many more common species that can occur in the lakes system in quantities of state or national significance. These include Black Swan, Chestnut Teal, Eurasian Coot, Great Cormorants and Musk Duck.

**Fish**

A wide range of fish species use or inhabit the lakes, including bream, bass, perch, galaxias, mullet, eels, trevally, seahorses, flathead and carp. Many form the basis of valuable recreational and commercial fisheries. The species are largely distributed within the lakes system according to their salinity preferences and tolerances as illustrated in Figure 1. The guilds of fish that are present in the Gippsland Lakes clearly illustrate that much of the lakes system is estuarine: estuary-dependent taxa make up one-fifth of all fish species, and marine taxa that use the estuary opportunistically make up a further 28%.

![Fish groups found in the Gippsland Lakes, their distribution and the percentage of species in each group as a percentage of the 179 species found in the lakes](image)
Species of conservation significance

The Gippsland Lakes system is also valuable because it supports numerous animal and plant species and communities of state, national and international conservation significance.

As well as the migratory waterbird species that are protected under international agreement, a wide range of nationally important species and communities listed under the Australian Government’s Environment Protection and Biodiversity Conservation Act 1999 are present in the Gippsland Lakes area. These include the Growling Grass Frog, the Green and Golden Bell Frog, Painted Snipe, Australian Grayling, Dwarf Galaxias, Coast Grey Box and Gippsland Red Gum Grassy Woodland. Species of other conservation significance include Swamp Skink, Australasian Bittern, Australasian Shoveler, Great Egret, Hardhead and Royal Spoonbill.

2.3 Social and economic values

The Gippsland Lakes system has significant social and economic value to Gippsland as well as to the rest of Victoria. The fact that the lakes are listed as a Wetland of International Significance means that their biodiversity values are also recognised at national and international levels.

Economic assessments commonly distinguish between market and non-market values. The main market values of the Gippsland Lakes are commercial fisheries (which targets fish species such as Black Bream, European carp, Dusky Flathead, Yellow-Eye Mullet, Tailor and Silver Trevally) and tourism. Tourism is well developed in the Gippsland Lakes area and provides employment of local people, accommodation for visitors and a major contribution to the local economy.

Non-market values include recreation in the form of boating, swimming, fishing, nature walking, camping and general sightseeing. Other than recreation, non-market services also include visual amenity and the intrinsic value of biodiversity and wildlife. These latter values or services in particular are not priced but are still highly valued by society.

2.4 Physical characteristics

Hydrology

Water enters the Gippsland Lakes as surface water runoff (from 20,500 km$^2$ of catchment, about one-tenth of the area of Victoria), rain falling directly on the lakes, groundwater and ingress of seawater through the entrance.

Although there are over a dozen streams and rivers that supply freshwater to the lakes system, most freshwater inflows are delivered to by seven rivers. The Latrobe River (44% of mean annual inflow including the Thomson River) and the Mitchell River (35% of mean annual inflow) are the largest contributors of freshwater to the main lakes. The Avon (8% including the Perry River), Tambo (11%) and Nicholson rivers (2%) make up the balance.

Although groundwater inflows make a relatively small direct contribution to the water balance of the lakes system, there is strong evidence that discharge from the watertable to the various tributary rivers is likely to make a significant indirect contribution to the Gippsland Lakes. The watertable mainly receives recharge from rainfall and irrigation, with some minor...
upwards leakage from deeper aquifers such as the Boisdale Aquifer. Groundwater discharge contributes about 24 to 36% of annual average flow in the Avon River during periods of average rainfall. Similar contributions are expected for the other major rivers, particularly the Mitchell.

Natural inflow to the Lakes is illustrated by the time series of annual ‘natural’ river flows as shown in Figure 2.

Figure 2  Time series of annual ‘natural’ river inflows to the Gippsland Lakes 1965–2003

The hydrological record demonstrates both high inter-annual and intra-annual variability in riverine inflows to the Gippsland Lakes system. Floods can be 1000 to 10,000 times greater than non-flood flows.

Each of the inflowing rivers contributes freshwater with different volumes, frequency, timing and duration and quality to different parts of the Gippsland Lakes system. There is therefore a spatial as well as a temporal component to the variability of inflow.

Water extraction

About 20% of the available average annual riverine discharge to the Gippsland Lakes is extracted as surface water for agricultural, industrial and domestic purposes before it reaches the lakes. River regulation and extraction of water is greatest for the western rivers (96% of total extraction). In contrast, flows in the eastern rivers are largely unregulated and average annual extraction represents a significantly smaller proportion of flows (although the majority of extraction occurs in summer and autumn when flows are lowest).

1 Note that these flows are not truly representative of natural conditions. They are modelled flows representing the flows that would have occurred without existing river regulation or diversions for irrigation or other use however no account is taken of other changes in catchment characteristics (such as clearing of vegetation, forestry, drainage works, etc).
The Latrobe River system has been most affected by regulation and extraction. Surface water extraction and storage from the Latrobe, Thomson and Macalister rivers has reduced freshwater inflows to Lake Wellington to the extent that, on average, discharge is now reduced from natural conditions by 33%. The impact of current extractions on river flows is illustrated in Figure 3. It is estimated that full practical usage of existing water entitlements would reduce riverine discharges to the entire system by a further 8% (of current inflow). This would equate to a total reduction of approximately 44% from natural inflows for the Latrobe River system.

![Figure 3](image.png)  
**Figure 3**  Average annual discharge and surface water extraction from the major rivers entering the Gippsland Lakes system. The flow data is for the period 1965 to 2003.

The above figures do not account for extraction of groundwater from aquifers that are hydraulically connected to the inflowing river systems. Such extractions reduce groundwater contribution to river flows and hence the volume of freshwater entering the Gippsland Lakes. The extent to which this occurs in the Gippsland Lakes catchments has not been determined. However, a recent investigation in the Avon River catchment suggested that groundwater pumped from the shallow aquifer would ultimately result in a reduction in streamflow of nearly the same volume. Therefore, groundwater extractions are an important (but often overlooked) factor in the overall water balance of the river systems that drain into the Gippsland Lakes.

**Water levels and flow**

The opening to the Southern Ocean at Lakes Entrance provides a permanent but very constricted connection between the lakes and the sea. The nature of this connection has important ramifications for water levels and salinity regimes across all of the lakes system.
Because of the restricted connection to the sea, large inflows of freshwater during floods cause an increase in water levels in the main lakes and flooding in nearby low lying areas. Lake water level will increase up to 1.8 m and 2.2 m at Lakes Entrance and Lake Wellington respectively in the event of a 1 in 100 year flood. Elevated water levels last for several days, until flows out through the entrance return water levels to normal.

Diurnal tidal influences are largely damped out, and oceanic tides result in only small (< 0.1 m) water level fluctuations in the lakes. On the other hand, longer period (> 1 week) changes in ocean water level (mostly arising from changes in atmospheric pressure or storm surge) can result in changes in the water levels of up to 1 m in the main lakes. Figure 4 demonstrates the relationship between water levels in the ocean and water levels in Lake King.

![Figure 4 Gippsland Lakes tidal response. Upper plot: measured water levels offshore from Lakes Entrance and mean ocean level filtered from tidal data. Lower plot: measured water levels in Lake King for the same period, with mean ocean level superimposed, but lagged by 24 hours. Time axis is in hours, water level axis is in m AHD (approx).](image)

Notwithstanding ocean effects, the main driver of circulation processes in the Gippsland Lakes is wind set-up. Wind set-up can induce a water surface gradient and account for up to 1 m water level difference between one end of the lakes system and the other.

**Salt water exchange**

Prior to the establishment of the permanent marine entrance at Lakes Entrance in 1889, the Gippsland Lakes was a predominantly freshwater system cut off from the Southern Ocean by the coastal barrier dune system. The lakes were an intermittently open-and-closed lagoon system that was normally fresh or at times brackish. Floods would create a temporary opening to the ocean, allowing an episode of seawater incursion before sand accumulations resealed the opening.
Since construction and maintenance of the permanent entrance, saline water has almost permanently intruded into the lake system. Lakes Victoria and King now have an average salinity half that of seawater. As in a classic estuary, salinity levels in the lakes vary with the rate of freshwater inflow. During floods, salty water is pushed out through the entrance and the lakes become fresher. During periods of low flow, saline water gradually intrudes and can extend through the system. Salinity can penetrate far upstream into the inflowing rivers.

A further consequence is that denser saline water now accumulates in the deeper parts of the lakes system with freshwater flowing over the top, as a surface layer. The vertical stratification of the water column as shown in Figure 5 is created by the difference in densities of seawater and freshwater. This near-permanent stratification has important implications for nutrient regeneration and the occurrence and severity of algal blooms in the main lakes.

Some wetlands on the western side of Lake Wellington also receive increased salt loads from their surrounding catchments. These salts are mobilised by elevated watertables driven by excess recharge from irrigation and catchment clearing. The relative significance of this salt source to individual wetlands varies with their proximity to Lake Wellington and areas of secondary salinisation.

**Salinity regime**

The Gippsland Lakes system currently has a salinity regime that is highly variable both in time (from season to season and from year to year) and in space (from place to place within the lakes system and vertically within the water column). The salinity regime and its variability depend on the ingress of salt water from the ocean through the entrance and its dilution via inflows of freshwater to the lakes from the rivers and streams that discharge into them.
In contrast to pre-entrance conditions, when ingress of seawater was a temporary phenomenon dependent on intermittent breaches in the barrier dune, the artificial permanency of the current entrance has created a constant boundary condition for the lakes. As a result, variability in salinity is now almost solely the result of variability in freshwater inflows from the main rivers. The dependence of salinities on freshwater inflows is illustrated in Figure 6 by a typical sequence in the period 1992–95. Periods of low river discharge are correlated with periods of high lake salinity, and vice versa.

![Lakes Inflow and Salinity](image)

**Figure 6** Dominant effect of inflow on salinity. Typical period pre-1997 in Lake King (psu = practical salinity units = g/L).

Figure 7 illustrates the results of salinity modelling of Lake Wellington for the Central Region Sustainable Water Strategy. The figure demonstrates both:
- the temporal variability of salinity in Lake Wellington and
- the impact of reduced inflows to Lake Wellington from water extraction upstream.

The median salinity concentration of Lake Wellington has increased from 4.6 to 8.1 ppt (an increase of 3.5 ppt or 76%) as a result of existing river regulation and diversion.

The combined effect of the permanent entrance and the reduction in freshwater inflows to the lakes caused by river regulation and water extraction and a drying climate has been to shift the salinity regime of the lakes as a whole from a mostly freshwater-brackish system to one that is strongly estuarine and highly variable. The probable change from a pre-entrance regime to the current regime is shown in broad and indicative terms in Figures 8 and 9.
Figure 7  Modelled salinities in Lake Wellington for current and “natural” scenarios. Note that the “natural” scenario has upstream water extraction reduced to zero but still includes the effect of the artificially permanent entrance.

Figure 10 demonstrates the likely combined effect of worst case (step) climate change and continued consumptive water use, which is to move the system to predominantly marine conditions with only periodic influx of significant volumes of freshwater during floods. The implications of these changes for future management of the Gippsland Lakes system are discussed in Sections 3 and 4.

The effect of worst case (step) climate change on inflows to the lakes may be even greater than the 20% reduction already attributable to agricultural, domestic and industrial water use. A continuation of post-1997 climate conditions means a reduction of 34% in inflows to the lakes (compared to natural inflows). The combined effect of step climate change and future consumptive water use could be to reduce the inflows to the Gippsland Lakes to less than half their natural inflows. This reduction is predicted to be greatest for the western rivers, with a 68% reduction of inflows to Lake Wellington and a 28% reduction to Lake King (compared to natural inflows).

As well as reduced inflows, climate change is also predicted to lead to a general rise in lake levels of 0.3 to 0.6 m by 2100 as the result of sea level rise.

Significant areas of the catchments of the Gippsland Lakes have been affected by wildfire in recent years: the alpine fires of 2002–03, the Great Dividing Range fires of 2006–07, and the very recent Strzelecki fires of 2009. Regeneration of forest following wildfire can result in initial short-term increases in catchment water yield, and then subsequent decreases for many decades, with the impact being dependent on the extent and severity of the fire and the type of vegetation affected. Under historical rainfall conditions, and in the absence of future fires, preliminary estimates are that the maximum reductions in mean annual flow from pre-fire conditions for individual catchments flowing into the Gippsland Lakes will be between 2-12%, with the overall impact on flows into the Lakes being around 7%.
Figure 8  Probable salinity regime in the Gippsland Lakes system prior to the establishment of the permanent entrance to the ocean at Lakes Entrance

Figure 9  Current salinity regime in the Gippsland Lakes system
Figure 10 Likely salinity regime in the Gippsland Lakes system in 2050 if estimated reductions in freshwater flows due to worst case (step) climate change occur, combined with continuing consumptive water use.

2.5 Mega-habitats

Based on the major physical and habitat features, and then secondarily on salinity regime, water depth and intermittency, the Gippsland Lakes system was sub-divided into three ‘mega-habitats’ for the purposes of this study.

These are:

- **main lakes** (divided further into deep lakes and shallow lakes)
- **fringing wetlands** (subsequently divided into freshwater wetlands, variably saline wetlands and hypersaline wetlands)
- **estuarine reaches** of the major inflowing rivers.

The distribution of the three mega-habitats is shown in Map 3 and the key characteristics of each are described in the following pages.
Map 3 Overview of the mega-habitats of the Gippsland Lakes system
Main lakes

The main lakes include the permanent deep water bodies such as Lake King and Lake Victoria and the permanent shallow water bodies such as Jones Bay and Lake Wellington (see Map 4).

Four species of seagrass occur in the main lakes, with their distribution determined by water and salinity regimes. Biofilms and algae that grow on the seagrass leaves, as well as larger benthic algae that grow between seagrass plants, are crucial components of food webs in the Gippsland Lakes. Seagrass beds also provide habitat and food for fish and several species of birds, notably Black Swan, Eurasian Coot and Little Tern.

Phytoplankton (also commonly referred to as free-floating algae) occur in each of the mega-habitats but are most prominent in the main lakes where they frequently reach bloom concentrations. The lakes are susceptible to algal blooms because:

- they experience episodic periods of high nutrient loads from the catchment.
- differences in salt concentrations allow the water column to stratify vertically, creating favourable physical conditions for rapid algal growth.
- submerged macrophytes, such as seagrasses or the freshwater plant Vallisneria, that may compete with the algae for nutrients, cover little of the sediment area.
Map 4  Main lakes mega-habitat of the Gippsland Lakes system
Fringing wetlands

Extensive fringing wetlands occur throughout the lakes system, often in proximity to river mouths.

They include:

- **freshwater wetlands** such as Sale Common and Macleod Morass
- **variably saline wetlands** such as Heart Morass, Clydebank Morass and Dowd Morass
- **hypersaline wetlands** such as Lake Reeve and Victoria Lagoon (see Map 5).

Fringing wetlands are characterised by vegetation communities of Swamp Paperbark (*Melaleuca ericifolia*), Common Reed (*Phragmites australis*), submerged and emergent aquatic plants and diverse saltmarsh species and are a vital habitat and food source for numerous bird and fish species. Many are also an important component of regional landscape aesthetics. Many of the inhabitant bird and fish species require fresh or brackish conditions, at least for breeding.
Map 5  Fringing wetlands mega-habitat of the Gippsland Lakes system
Estuarine reaches of rivers

Estuarine characteristics extend well upstream in all the inflowing rivers, determined by the maximum extent of saline intrusion (see Map 6).

The estuarine reaches of rivers have particular importance for the maintenance of fish populations, providing suitable salinity conditions for breeding in proximity to seagrass and shoreline habitat and food sources. The extent of saline intrusions is important also in controlling the upstream migration of vegetation and thus animal habitat.
Map 6  Estuarine river reaches mega-habitat of the Gippsland Lakes system. The illustrated estuarine extent in the eastern rivers is the maximum extent of salt wedge penetration as limited by in-stream barriers. In the western rivers, the illustrated estuarine extent is indicative of the typical extent of the salt wedge under low flows.
3 The role of freshwater inflows in the ecological health of the Gippsland Lakes system

This section of the scoping study report explores the extent of existing knowledge about the relationship between hydrology and ecology in the Gippsland Lakes system. It draws inferences about the functions of freshwater inflows based on a review of international literature as well as Gippsland Lakes-specific studies, and provides a compilation of the flow dependencies of the three mega-habitats. The overall state of existing knowledge is also discussed.

3.1 Generic inferences

Riverine inflows to the Gippsland Lakes are characteristically low by world standards, highly variable and seasonal. This strong intermittency means that the normal time it takes for water to move through the lakes is quite long except that rapid flushing takes place during floods. The spatial variation in salinity, from the marine-influenced areas near the ocean to the most freshwater reaches upstream, is therefore overlayed with a strong temporal variability. The magnitude, frequency, duration, timing and quality of freshwater inflows dominates the salinity, sediment and nutrient regimes of the lakes system, and therefore its ecological structure and function.

Salinity regimes and their ecological implications

The ecological values of the Gippsland Lakes system (and related social and economic values) rely heavily on the interaction of seawater and fresh water within the lakes, wetlands and their tributary streams. The characteristically variable salinity regime provides a set of conditions that supports estuarine conditions within the main lakes and lower reaches of the inflowing rivers. Much remains unknown about the detailed functioning of physical and biological processes in the Gippsland Lakes system. It is clear, however, that the salinity regime is dominated by the magnitude, frequency, timing and duration of freshwater inflows, and the existence of an artificially permanent opening to the ocean at Lakes Entrance. In turn, the major ecological, social and economic values of the system currently depend directly and indirectly on the salinity regime.

Although salinity exerts a near-overwhelming influence on the structure and function of estuarine systems such as the Gippsland Lakes, it is not the only freshwater-dependent variable affected by the relationship between marine and riverine inputs.
- Freshwater inflows are critical also for the importation of nutrients and suspended solids, two factors that influence strongly the growth of phytoplankton, benthic macroalgae and seagrasses in estuaries.
- Toxicants are influenced also by freshwater inflows, both in terms of importation from the catchment and bioavailability and mobility within the estuary and its biota.
- Fundamental ecosystem processes, such as rates of primary production and decomposition pathways, are influenced by the magnitude and timing of riverine inputs of fresh waters to estuaries.
Continuing impacts of the permanent entrance - An example of long term and complex response

The opening of the artificial entrance at Lakes Entrance in 1889 had two major consequences for the Gippsland Lakes. The first and immediate consequence was to modify the range of water levels in the main lakes. Before 1889, riverine discharge and rain-water inputs could cause water levels in the main lakes to rise by as much as ~2 m when the entrance was closed. High water would persist until the sand berm was breached (usually by floods) and the accumulated water escaped to the Southern Ocean. The second impact has been to increase the salinity of the Gippsland Lakes, which previously were relatively fresh because of their intermittent linkage with the ocean and large riverine inputs.

It was proposed by the geomorphologist Eric Bird as early as the 1960s that increased salinity in the Gippsland Lakes would cause Swamp Scrub communities, dominated by the Swamp Paperbark *Melaleuca ericifolia*, to replace the existing communities of Common Reed, dominated by *Phragmites australis*, that once fringed the lakes, wetlands and lower reaches of the rivers. Eventually, salinity would become so high that even Swamp Paperbarks in this wetland. It is also likely that, under conditions of near-permanent inundation in Dowd Morass, the presence of micro scale relief has played a major role. It is also likely that, under conditions of near-permanent inundation in Dowd Morass, the presence of micro scale relief has played a role in allowing Swamp Scrub to become the dominant vegetation type and slowly replace Common Reed.

There is some evidence to support this prediction, as an analysis of historical aerial photographs of Dowd Morass has shown the progressive loss of Common Reed communities and their replacement with Swamp Scrub since the 1960s (Boon et al. 2008). Although such a shift is consistent with the predictions made by the model of vegetation change proposed by Bird, it is unlikely that salinity from the Entrance alone is the factor responsible for the increasing dominance by Swamp Paperbarks in this wetland. Reduction in freshwater inflow has also played a major role. It is also likely that, under conditions of near-permanent inundation in Dowd Morass, the presence of micro scale relief has played a role in allowing Swamp Scrub to become the dominant vegetation type and slowly replace Common Reed.

In other areas that fringe the northern and southern shores of Lake Wellington, however, it has been observed that Swamp Scrub has developed an understory of saltmarsh and, in some cases, has even been replaced by hypersaline mudflats without any vegetation at all. These changes are consistent with Eric Bird’s predictions, and may represent a continuation of the shift in vegetation that probably commenced within a few decades of the artificial entrance being opened.

For example, the salinity regime dictates:

- the distribution and condition of Swamp Paperbark (*Melaleuca ericifolia*) and Common Reed (*Phragmites australis*) vegetation associated with fringing wetlands and riparian zones of the lower reaches of the inflowing rivers
- the distribution, condition and composition of submerged aquatic plants in the main lakes and fringing wetlands, in particular those with freshwater affiliations (for example *Vallisneria*, *Potamogeton* and *Triglochin* spp.) and seagrasses
- fish populations, via the availability of critical habitat, food supplies and the continued existence of life cycle cues for successful recruitment
- the strength and extent of water-column stratification in the main lakes, with implications for the incidence and severity of noxious algal blooms
- the risk of invasion by exotic species of pest plant and animal species, including noxious macroalgae and marine invertebrates.
Physical conditions that support ecological values

Research for the scoping study has identified the following links between ecological values of the Gippsland Lakes system and physical habitat conditions (Table 1). These physical conditions are directly or indirectly influenced by freshwater inflows, or need to be coupled with particular inflow events.

Table 1  Summary of physical conditions that support key ecological values of the Gippsland Lakes system

<table>
<thead>
<tr>
<th>Ecological values</th>
<th>Physical conditions that support key values</th>
</tr>
</thead>
<tbody>
<tr>
<td>Black Bream</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Suitable spawning conditions for Black Bream include:</td>
</tr>
<tr>
<td></td>
<td>-  <strong>Water column salinity:</strong> brackish water (17-21 g/L) in the middle of the water column, therefore spawning is strongly associated with the location of the salt wedge and the length of the halocline.</td>
</tr>
<tr>
<td></td>
<td>-  <strong>Location of salt wedge:</strong> within the mid-lower section of the estuarine river reach, or just out into the main lakes, as opposed to being far up the river (approx. &gt;10km upstream of the river mouth) or well-out into the lakes (approx. &gt;5km from the river mouth). This is based on the likelihood of larvae being transported to suitable rearing habitat (see below). This is most likely maximised in the middle-lower part of the river estuary, with small channel size reducing habitat in the upper section and the deeper areas of the main lakes not providing a suitable rearing habitat for pelagic larvae.*</td>
</tr>
<tr>
<td></td>
<td>-  <strong>Length of halocline:</strong> the more elongated the halocline, the greater the area of brackish water available for spawning.</td>
</tr>
<tr>
<td></td>
<td>-  <strong>Timing:</strong> October – December</td>
</tr>
<tr>
<td></td>
<td>-  <strong>Temperature:</strong> 18 – 24°C</td>
</tr>
<tr>
<td></td>
<td>• Suitable conditions for larval Black Bream include:</td>
</tr>
<tr>
<td></td>
<td>-  <strong>Habitat:</strong> Larvae are rarely found and are easily flushed out of the rivers with higher flows. Larvae have been found in Phragmites reed beds in rivers.</td>
</tr>
<tr>
<td></td>
<td>-  <strong>Food source:</strong> zooplankton, which are generally tightly coupled with the halocline.</td>
</tr>
<tr>
<td></td>
<td>• Suitable conditions for juvenile Black Bream include:</td>
</tr>
<tr>
<td></td>
<td>-  <strong>Habitat:</strong> submerged aquatic vegetation i.e. Phragmites reed beds and macroalgae in the estuarine river reaches, and seagrass in the main lakes.</td>
</tr>
<tr>
<td></td>
<td>-  <strong>Food source:</strong> phytoplankton, which are generally tightly coupled with the halocline.</td>
</tr>
<tr>
<td></td>
<td>• Reduced frequencies of algal blooms. The quality and quantity of habitat available for adult and juvenile Black Bream can be directly or indirectly reduced by algal blooms. E.g. epiphytic algal growth on seagrass causing dieback; reductions in bottom water oxygen concentrations affecting fish access to shelter, food and possibly predation by waterbirds.</td>
</tr>
<tr>
<td>Ecological values</td>
<td>Physical conditions that support key values</td>
</tr>
<tr>
<td>-------------------</td>
<td>---------------------------------------------</td>
</tr>
</tbody>
</table>
| Swamp Scrub       | • Inundation approximately once every 2 years, ideally in winter/spring, with low salinity water (<2 g/L).  
|                   | • Dry periods for several months every 3-5 years for optimum vegetation growth.  
|                   | • Through-flow of freshwater approximately once every 5 years to import and export organic matter, sediment, salt, nutrients and biota, and promote large scale waterbird feeding/breeding events.  
|                   | • Water column salinity concentrations less than 2 to 4 g/L to ensure good germination rates of Swamp Paperbark. Seed germination is poor to non-existent above 16 g/L. |
| Estuarine biota (including fish, riparian vegetation, waterbirds, submerged vegetation, invertebrates) | • Variable salinity regime including occasional short-term salinity reductions in main lakes to support estuarine biota by reducing competition from marine species that cannot tolerate salinities much less than seawater (i.e. < 35 g/L).  
|                   | • Creation of saline stratification in the lower river to support estuarine biota.  
|                   | • Minimise occurrence of well mixed, unstratified conditions which are dominated by higher salinity lake waters. Such conditions are potentially unsuitable for estuarine biota.  
|                   | • Transportation of wood and logs, organic matter, sediment, nutrients and biota, which are all important for habitat and biological production.  
|                   | • Presence of nearby standing areas of vegetated freshwater for waterbird drinking and roosting.  
|                   | • Flushes of water laden with organic matter and other food sources encourage fish feeding and breeding cycles. |
| Saltmarsh         | • Through-flow of freshwater approximately once every 5 years to import and export organic matter, sediment, salt, nutrients and biota, and promote large scale waterbird feeding/breeding events.  
|                   | • Periods of low salinity are required to allow the seeds of saltmarsh vegetation to germinate and for young plant to establish.  
|                   | • Presence of nearby standing areas of vegetated freshwater for waterbird drinking and roosting. |
Ecological values

<table>
<thead>
<tr>
<th>Physical conditions that support key values</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Salinities less than 15 g/L in surface waters.</td>
</tr>
<tr>
<td>2. Water temperatures above 24°C.</td>
</tr>
<tr>
<td>3. Strong, persistent stratification of the water column is an essential pre-cursor to anoxic conditions in the bottom waters of the main lakes. Anoxia promotes the release of stored phosphorus from the sediments, making it available for uptake by algae.</td>
</tr>
<tr>
<td>4. Still conditions where turbulence of the water column is reduced. Under low flows stratification is more influence by wind strength and direction.</td>
</tr>
<tr>
<td>5. High nutrient concentrations in the water column, particularly nitrogen, which initiates diatom and/or dinoflagellate blooms, which subsequently die and conditions then favour the nitrogen-fixing Nodularia spumigena.</td>
</tr>
</tbody>
</table>

*NHabitat requirements of Black Bream are broadly similar to other estuarine fish species in which spawning is also influenced by the location and extent of the salt wedge, such as Estuary Perch and Australian Bass.

Flow-ecology relationships: Breaking them down

Most aspects of the physical habitat requirements of aquatic biota are directly affected by water flows. Physical habitat requirements include patterns in water quality (e.g. salinity, temperature, nutrient concentrations), water depth and velocity, in time and space. A conceptual diagram of these ‘flow-ecology relationships’ is adjacent.

The flow-ecology relationships operating in estuarine environments are highly complex compared to the freshwater reaches of rivers. This is because of the complex interactions between freshwater and saline inflows, and the movement of water from rivers into adjoining lakes and wetlands. As a result, the outputs from riverine environmental water requirements studies tend to produce relatively detailed flow regimes based on individual flow components, whereas estuarine studies tend to address environmental water requirements at broader hydrological scales.
Ecological effects of altered freshwater discharges

Based on an assessment of widely applicable estuarine processes, the range of possible impacts of reduced freshwater inflows on the Gippsland Lakes system and their associated habitats is summarised in Table 2.

Table 2  Ecological consequences of altered freshwater discharge on estuaries such as the Gippsland Lakes

<table>
<thead>
<tr>
<th>Driving factor</th>
<th>Likely ecological consequences</th>
</tr>
</thead>
</table>
| Smaller annual discharge | Loss of saltmarsh habitat  
Nutrient deficiencies in saltmarshes  
Reduced germination of saltmarsh and seagrass taxa  
Restricted upstream fish migration  
Reduced access to juvenile fish rearing habitat  
Lack of environmental triggers for fish spawning or movement  
Reduced recruitment of fisheries to estuaries  
Reduced production of fish and other aquatic animals (fin fish, bivalves, crustaceans)  
Reduced foraging and nesting habitat for birds  
Altered water temperatures |
| Increased salinity | Potential for hypersaline waters to develop in adjacent wetlands/saltmarshes  
Seagrasses colonise upper reaches of estuary  
Decline of some seagrass species (e.g. less salt-tolerant taxa)  
Loss of fringing macrophytes and possible replacement with exotic taxa  
Reduced algal growth rates and increased herbivory  
Increased risk of invasion by noxious oceanic species (plant and animal)  
Increased number (and diversity) of marine fish taxa in estuarine waters |
| Altered sediment load and deposition | Altered seagrass distribution and condition  
Altered abundance of turf-forming algae (via both top-down and bottom-up impacts)  
Decreased recruitment, growth and survival of macroalgae  
Altered abundance and diversity of meiofauna (i.e. sediment dwelling invertebrates)  
Interference with filter-feeding macrofauna (e.g. mussels) |
| Decreased nutrient load | Reduced algal productivity  
Reduced estuarine productivity (e.g. oysters) |
| Increased water clarity | Increased predation of fish by waterbirds or by other visual predators  
Increased depth distributions of seagrasses  
Increased growth of microphytobenthos (i.e. lake bed algal mats)  
Altered water temperatures |
3.2 Flow dependencies of the mega-habitats

Ecological functioning in the lakes system is influenced by the salinity regime and inputs of nutrients, sediments and organic material. In turn the salinity regime and inputs of nutrients, sediments and organic material depend not just on the annual volume of freshwater inflows but on the frequency, duration, timing and magnitude of the inflows. The functions that selected flow components have in the health of the lakes system are summarised below for each mega-habitat. It is clear that spatial and temporal variability is a critical requirement for freshwater inflows to the Gippsland Lakes system.

In some instances, investigators have postulated thresholds for those flow characteristics considered to be important to ecological responses in the Gippsland Lakes system. A selection of these flow thresholds is summarised below for each mega-habitat. While the thresholds convey important information about the nature of the dependencies and give an indication of the magnitude of some of the related flow characteristics, the thresholds represent an incomplete and unverified set of interpretations that do not deal consistently with magnitude, frequency, duration or timing of flows. Therefore these thresholds cannot be solely relied upon to set environmental flow requirements.

Fringing wetlands

Tables 3 and 4 summarise the flow components and indicative flow thresholds relevant to the fringing wetlands mega-habitat.

Table 3 Flow requirements, flow components and their function for the fringing wetlands

<table>
<thead>
<tr>
<th>Overview of flow requirements</th>
<th>Flow components</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ecological condition of fringing wetlands is closely linked to influxes of fresh water, predominantly in spring. Both wetting and flushing flows are needed to maintain vegetation and habitat values – at least every 2nd and 5th year respectively. Dry periods of several months are desirable every 3 to 5 years.</td>
<td>Flushing flow</td>
<td>Prolonged high overbank flows provide connectivity between habitats, inundate wetlands, decrease water-column salinity and flush accumulated salt from sediments, introduce new nutrients and sediments and transport plant and animal propagules. Vital for sustainability of Swamp Paperbark communities and probably also for Common Reed.</td>
</tr>
<tr>
<td>Wetting flow</td>
<td>A short period of overbank flow waters Swamp Paperbark and other species and relieves them from periodic water stress.</td>
<td></td>
</tr>
<tr>
<td>Drying out</td>
<td>To prevent tree death from waterlogging and facilitate decomposition of accumulated organic matter available for uptake upon re-wetting. A risk now exists with activation of acid sulphate soils following modification to the natural wetting and drying cycles.</td>
<td></td>
</tr>
</tbody>
</table>
Table 4  Summary of indicative flow thresholds for ecological conditions in the fringing wetlands

<table>
<thead>
<tr>
<th>River system</th>
<th>Indicative flow threshold</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lake Wellington tributaries</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Major wetlands fringing the lower Latrobe River (sum of flows in Thomson and Latrobe rivers)</td>
<td>≥13 GL/day to partly inundate Dowd Morass and Long Waterhole wetlands(^1)</td>
<td>Wetting flow for fringing wetlands. A short period of overbank flow waters Swamp Paperbark and other species.</td>
</tr>
<tr>
<td></td>
<td>≥19 GL/d to initiate inundation of the Heart Morass(^1)</td>
<td>Flushing flow for fringing wetlands provides connectivity, decreases salinity, flushes accumulated salt and organic matter, and introduces new nutrients, sediments and biological material</td>
</tr>
<tr>
<td></td>
<td>≥23 GL/day to partly inundate Sale Common(^1)</td>
<td></td>
</tr>
<tr>
<td>Major wetlands fringing the lower Avon River (flow in the lower Avon River)</td>
<td>≥66 GL/day to fill Clydebank Morass(^1)</td>
<td></td>
</tr>
<tr>
<td>Lake King tributaries</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Major wetlands fringing the lower Mitchell, Nicholson and Tambo rivers (flows in the lower reaches of these rivers)</td>
<td>Flow of 33 GL/day(^2) in the Mitchell, 19 GL/day(^2) in the Tambo and 6 GL/day(^2) in the Nicholson at least every 2nd year(^3)</td>
<td>Wetting flow for fringing wetlands. A short period of overbank flow waters Swamp Paperbark and other species</td>
</tr>
<tr>
<td>Major wetlands fringing the lower Mitchell, Nicholson and Tambo rivers (flows in the lower reaches of these rivers)</td>
<td>Flow of 53 GL/day(^2) in the Mitchell, 35 GL/day(^2) in the Tambo and 11 GL/day(^2) in the Nicholson at least every 5th year(^3)</td>
<td>Flushing flow for fringing wetlands provides connectivity, decreases salinity, flushes accumulated salt and organic matter, and introduces new nutrients, sediments and biological material</td>
</tr>
</tbody>
</table>

\(^1\)Threshold adopted from previous investigation based on physical survey and/or quantitative modelling.  
\(^2\)Threshold estimated for this investigation based on statistical or similar analysis of available hydrologic data. 
\(^3\)These estimates are likely to be low. Estimates for the lower Latrobe wetlands using the same technique are lower than estimates based on hydraulic analysis. 

Further Notes:  
1. Ecological responses are based largely on expert opinion.  
2. The thresholds proposed for wetland inundation do not take into account the existence of water control structures installed in individual wetlands that can be operated to artificially inundate these wetlands using river flows below bankfull height.  
3. Lake levels also influence flow thresholds.
Hydro-ecological interactions can be postulated with the greatest confidence in the fringing wetlands. The physical processes that control flows and flooding into and out of the wetlands are well understood, although the necessary data collection and analyses have been initiated only in four special cases (Clydebank, Heart and Dowd morasses and Lake Coleman). The conceptual relationship between the frequency, magnitude and duration of flooding and the response of some important plant species is also reasonably well understood, however the relationships are not yet fully quantified. Further, although there are no prescriptive models, the link from the health of the vegetation communities to the more general health of the wetland can be proposed with some confidence.

**Estuarine river reaches**

Tables 5 and 6 summarise the flow components and indicative flow thresholds relevant to the estuarine river reaches mega-habitat.

**Table 5 Flow requirements, flow components and their function for the estuarine river reaches**

<table>
<thead>
<tr>
<th>Overview of flow requirements</th>
<th>Flow components</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ecological values in the estuarine reaches of the rivers depend on movement of the halocline associated with variable flow periods in the river. Movement of the halocline is likely to be important for a number of ecological functions in the estuarine reaches. Not only does this ensure that flows into wetlands occur from the fresh water above the halocline, but movement of the halocline toward the mouth of the river or out into the shallow areas of the lakes where seagrass grows is thought to provide improved habitat for fish spawning and recruitment.</td>
<td>Annual flow</td>
<td>Drives the average extent and location of the salt wedge and has impacts on average lake salinity. Promotes breeding and recruitment of Black Bream and other estuarine-dependent fish species. Likely to have an impact on distribution and condition of fringing plant communities, especially Common reed.</td>
</tr>
<tr>
<td>Flow pulses</td>
<td>Drives variations in salt wedge extent and position. Promotes breeding and recruitment of Black Bream and other estuarine resident fish, and has impacts on fringing plant communities.</td>
<td></td>
</tr>
</tbody>
</table>
## Table 6  Summary of indicative flow thresholds for ecological conditions in the estuarine river reaches

<table>
<thead>
<tr>
<th>River system</th>
<th>Indicative flow threshold</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Lake Wellington tributaries</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Latrobe River downstream of the confluence with the Thomson River</td>
<td>≥175 GL/month (6 GL/day)(^1)</td>
<td>Expel salt wedge from lower Latrobe to benefit estuarine fish species</td>
</tr>
<tr>
<td><strong>Lake King tributaries</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mitchell River</td>
<td>≥115 ML/day(^2)</td>
<td>Creation of strongly stratified conditions in the lower river to support estuarine biota, particularly fish species and trigger spawning for estuarine resident fish species</td>
</tr>
<tr>
<td>Tambo River</td>
<td>≥91 ML/day(^2)</td>
<td></td>
</tr>
<tr>
<td>Nicholson River</td>
<td>≥119 ML/day(^2)</td>
<td></td>
</tr>
<tr>
<td>Mitchell River</td>
<td>≤11.5 ML/day(^2)</td>
<td>Flows less than this magnitude are likely to be associated with well mixed, unstratified conditions dominated by higher salinity lake waters. Such conditions are potentially unsuitable for estuarine resident fish species</td>
</tr>
<tr>
<td>Tambo River</td>
<td>≤9.1 ML/day(^2)</td>
<td></td>
</tr>
<tr>
<td>Nicholson River</td>
<td>≤11.9 ML/day(^2)</td>
<td></td>
</tr>
</tbody>
</table>

\(^1\)Threshold adopted from previous investigation.  
\(^2\)Threshold estimated for this investigation based on statistical or similar analysis of available data.

Further Notes:  
1. Ecological responses are based largely on expert opinion.  
2. Lake levels also influence flow thresholds.
For the estuarine river reaches, the most important physical response to freshwater flows is movement in the length and location of the halocline. Again the physical processes that control this phenomenon are well understood and can be modelled, but data are inadequate or sparse for most rivers and no detailed analyses have been undertaken that would allow the behaviour of the halocline to be predicted with confidence for any particular case. Ecological response is poorly understood. It is known that the length and location of the halocline will have an important effect on fish breeding and habitat availability, plant distributions and vigour and other ecological processes, but the details are understood at a conceptual level only. The relationship between Black Bream and freshwater flows in the lower river reaches of the Mitchell, Nicholson and Tambo rivers is the subject of ongoing research, but no details of this relationship for these particular rivers are available currently.

Main lakes

Tables 7 and tables 8 summarise the flow components and indicative flow thresholds relevant to the main lakes mega-habitat.

Table 7  Flow requirements, flow components and their function for the main lakes

<table>
<thead>
<tr>
<th>Overview of flow requirements</th>
<th>Flow components</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>Freshwater inflows stimulate ecological responses by providing organic material, nutrients and suspended solids and creating spatial and temporal variability of water levels, areas inundated and salinity.</td>
<td>Mean annual flow</td>
<td>Important influence on catchment-derived nutrient loads and produces spatial and temporal variability in salinity. Bulk flows that reduce salinity will benefit fringing reed beds, support estuarine fish species such as Black Bream, and support estuarine-feeding birds.</td>
</tr>
<tr>
<td>Flow pulses</td>
<td>Short-term variability in salinities creates a desirable environment for estuarine species and limits the incursion of marine specialist species into the lakes. Introduces pulses of sediments and nutrients, with effects on geomorphology, habitat availability, nutrient limitation and rates of primary production. (In the deep lakes, freshwater inflows also initiate stratification and nutrient release from the sediments, both important preconditions for algal blooms)</td>
<td></td>
</tr>
</tbody>
</table>
Table 8  Summary of indicative flow thresholds for ecological conditions in the main lakes

<table>
<thead>
<tr>
<th>River system</th>
<th>Indicative flow threshold</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lake Wellington tributaries</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lake Wellington (sum of inflows from Latrobe, Thomson, Avon and Perry rivers)</td>
<td>≥200 GL/month(^2)</td>
<td>Short-term salinity reduction to support estuarine biota in Lake Wellington</td>
</tr>
<tr>
<td>Lake Wellington (sum of inflows from Latrobe, Thomson, Avon and Perry rivers)</td>
<td>≥130 GL/month(^1)</td>
<td>Sustained flow required to prevent saline intrusion into Lake Wellington</td>
</tr>
<tr>
<td>Lake Wellington (sum of inflows from Latrobe, Thomson, Avon and Perry rivers)</td>
<td>≥100 GL/month(^2)</td>
<td>Maintenance of estuarine conditions in lake to support estuarine fish species</td>
</tr>
<tr>
<td>Lake King tributaries</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lakes King and Victoria (sum of inflows from Mitchell, Nicholson, Tambo, Latrobe (includes Thomson River) and Avon (includes Perry River)</td>
<td>≥2500 GL/year(^2)</td>
<td>Maintenance of suitable salinity to support estuarine species (mainly in Lakes King and Victoria)</td>
</tr>
<tr>
<td>Lake King (sum of inflows from Mitchell, Nicholson, Tambo, Latrobe (includes Thomson River) and Avon (includes Perry River)</td>
<td>≥500 GL/month(^2)</td>
<td>Provision of short reduced salinities to support estuarine biota and deter marine biota</td>
</tr>
</tbody>
</table>

\(^1\)Threshold adopted from previous investigation based on quantitative modelling.
\(^2\)Threshold estimated for this investigation based on statistical or similar analysis of available data.

Further Notes:
1. Ecological responses are based largely on expert opinion.
2. Lake levels also influence flow thresholds.
The Lake Wellington Story
- crossing a condition threshold

Ecological research and modelling undertaken over the past two decades has shown that shallow lakes can exist in a number of stable states. In one state, the vegetation is dominated by rooted submerged plants and the volume of free-floating algae is usually low. In a second state, however, algae dominate the lake and there are few vascular plants growing along the bottom sediments.

The shift from a state dominated by vascular plants to one dominated by algae can be brought about by a range of environmental factors, including rapid increases in salinity, prolonged drying out of the lake, inadvertent pollution with herbicides, or the introduction of noxious fish.

Most recently, it has been shown that shallow lakes can exist in a range of states other than ones dominated by either vascular plants or free-floating algae: examples of other states include dominance by floating plants or dominance by benthic algal mats. In all cases, however, it is recognised that once a shift has occurred from one state to another, it is near impossible to reverse the change: in other words, the lake system exhibits considerable hysteresis.

It is highly likely that Lake Wellington underwent a change across vegetation states in the late 1960s. Before this time, the lake was vegetated with dense beds of the freshwater submerged plant *Vallisneria australis*.

It seems that progressive change from decreasing freshwater inflows and saline incursion from the entrance combined with drought and bushfire in the late 1960s culminated in the water column of Lake Wellington becoming salty and turbid, with the result that the beds of *Vallisneria* died.

The sediments then became unstable, and submerged vascular plants could not re-establish. Phytoplankton, however, could grow rapidly and quickly became the dominant vegetation in the lake. The dense populations of algae in the water column prevented light from penetrating to bottom sediments and, combined with the shifting nature of the substratum no longer stabilised by rooted plants, precluded the re-establishment of *Vallisneria* or other types of submerged angiosperms.

Thus today, Lake Wellington continues to be dominated by phytoplankton and rooted vascular plants are rare or non-existent. The absence of rooted plants has major implications for the ecological condition of the lake and may well contribute to Lake Wellington being a location where blue-green algal blooms are initiated in the Gippsland Lakes.

In the main lakes, salinity will impact directly on the mix of fish species and other biota because salinity affects physiology and life cycles. Salinity will also affect populations indirectly via impacts on habitat availability and food sources. The physical processes that control salinity regimes are sufficiently well understood to allow prediction of salinity impacts from changed freshwater inflows. The response of the fish population is known in general terms, but predicting the behaviour of specific species to changes in salinity and flooding regimes remains speculative. The influence of freshwater inflows on the incidence of algal blooms is the subject of ongoing work, and the accurate prediction of algal blooms in the lakes is still not a reality. Recent research has however identified a threshold for the annual load of nitrogen and phosphorus likely to cause an algal bloom.
3.3 State of existing knowledge

Based on widely applicable ecological principles and observations of historic change in the Gippsland Lakes system, this scoping study has confirmed the relationship between hydrologic change and ecological response in broad terms. While in some cases, observation and analysis has allowed quantitative thresholds of ecological response to be proposed, more generally, the information presented in this report relies on interpretation of qualitative conceptual models and broad ecological principles.

With few exceptions, the poor current understanding of the specific physical, chemical and biological processes that interact within the lakes system has precluded development, calibration and testing of reliable ecological response models. It also introduces an undesirably high level of uncertainty in the relationships that are proposed and, in some cases, even the understanding of qualitative responses is equivocal.

Key ecological response models are yet to be developed and adopted for the Gippsland Lakes system, at least to a resolution able to predict responses to incremental changes in system hydrology. Key relationships linking hydrologic and ecological characteristics have been described, and some indicative thresholds for a limited number of flow components are reported, but we remain a long way short of a prescription of the magnitude, duration, frequency and timing of the flow components that are required to maintain or improve the environmental condition of the Gippsland Lakes system in the short or long term. Physical, chemical and biological processes have been the subject of detailed study for a few isolated parts of the system (e.g. some fringing wetlands, development of algal blooms), but significant uncertainty remains and little or nothing is known about other important processes and interactions elsewhere in the system – particularly the ecological role of the halocline in the estuarine reaches of the rivers (currently the subject of research) and the role of freshwater inflows in increasing or decreasing the likelihood of algal blooms.

As an example of the poor current understanding, the results of quantitative modelling of ecological response that was undertaken for this study were largely equivocal. The reason for this was reported to be:

‘…uncertainty inherent in the causal chains linking flow through to the terminal nodes means that we lack the ability to make a strong prediction about the effect of changes in flow…’

The method used (Bayesian Network Modelling) is one of the most robust techniques currently available for organising and using diverse sources of information on ecological topics. The fact that Bayesian modelling, undertaken on three different types of biota in the Gippsland Lakes system, failed to show clear links between hydrologic change and ecological responses is at odds with the findings reported in the international literature and is most likely an indication of our current very poor understanding of the ecology of the Gippsland Lakes system and its relationship to hydrology.
The result of this is that while we can go some way toward understanding the trajectory of current ecological condition based on an interpretation of historical hydrologic and ecologic observations, our ability to predict ecological response to future hydrologic change is limited by the inadequacy of ecological response models. Even if there was enough knowledge to assign clear management objectives for the Lakes, there is no substantiated basis to prescribe the flows that would be required to achieve those objectives.

It is possible however, to use the knowledge of the Gippsland Lakes system that has been assembled here to establish the relative importance of freshwater inflows to the various values that have been ascribed to the system and to use that approach to assign spatial priorities for the determination of environmental water requirements.

We should not be too surprised by this knowledge barrier. Both the CEO of the Murray Darling Basin Authority and the Director of the CSIRO Water for a Healthy Country Flagship recently noted similar inadequacies in ecological response models for the Murray River as major impediments to environmental flow investigations in their jurisdictions (Australian Water Summit, Brisbane, June 2009).
4 Priority areas

The previous section of this scoping study report has used available generic and specific knowledge to infer the role of freshwater inflows in the ecological health of the mega-habitats of the Gippsland Lakes system. This section of the report uses that information to assess the relative sensitivity of the mega-habitats to hydrologic change, as the basis for proposing priorities for the determination of environmental water requirements.

4.1 Sensitivity to changes in freshwater inflows

A limited range of future freshwater inflow scenarios have been analysed to help understand the likely risks to ecological values from possible future flow changes. Generally, our existing knowledge of ecological response is insufficient to discern biological changes arising from relatively minor alterations in flow regime, such as increasing extractions from their current level to the limit of licensed diversions. Nevertheless, assessment of current and possible future flow conditions has allowed a broad classification of continuing and future impacts on ecological condition. Table 9 provides a ranking of the ecological impacts in each of the mega-habitats, for two potential future scenarios:

1. continued river regulation and water extraction, either at current levels of use or full uptake of existing entitlements (the difference is not significant for this investigation)
2. continued river regulation and water extraction with ‘worst case’ climate change projections – that is, ‘step’ climate change reflecting a continuation of post-1997 inflows.

This preliminary sensitivity assessment considers the impact on the current condition of the Gippsland Lakes system, which has already been significantly affected by the creation of the permanent entrance, river regulation and extraction, and a number of other pressures.

Although many of the ecological impacts have already occurred, the full effect of others may not yet have developed. Impacts on fish communities, for example, would probably have occurred soon after the creation of the entrance; historical evidence shows that changes to fringing reed beds were evident within the first few decades, but recent research shows that fringing wetlands are still adapting to altered hydrologic and salinity regimes. The assessment in Table 9 accounts for the probable continuing impacts of existing changes to freshwater inflows in addition to the likely responses to future reductions.
### Table 9  Relative sensitivity of ecological condition to reduced freshwater inflows, for two potential future flow scenarios

**Fringing wetlands mega-habitat**

<table>
<thead>
<tr>
<th>Cause</th>
<th>Ecological consequence</th>
<th>Relative sensitivity</th>
<th>Relative sensitivity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reduced annual discharge</td>
<td>Loss of saltmarsh habitat</td>
<td>Low</td>
<td>High</td>
</tr>
<tr>
<td>Nutrient deficiencies in saltmarshes</td>
<td>Lake Reeve and saltmarsh areas around the main lakes. Drier conditions could also see saltmarsh colonise areas currently too wet, so net changes in saltmarsh area are uncertain.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Reduced germination of saltmarsh plants</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Less frequent flooding of freshwater wetlands</td>
<td>Longer dry phases will encourage the spread of terrestrial species into areas that were formerly inundated for too long to support such species. Very long dry phases may see the loss of all wetland vegetation.</td>
<td>Low (eastern)</td>
<td>High (western)</td>
</tr>
<tr>
<td>Less frequent flooding of variably saline wetlands</td>
<td>For similar reasons to the last point, longer dry phases will encourage the spread of Swamp Paperbark unless salinity regimes become adverse. Very long dry phases may see the loss of all wetland vegetation, with poor chances of recovery due to limited connectivity between remaining sites and/or the activation of acid sulfate soils.</td>
<td>Low (eastern wetlands)</td>
<td>High (western wetlands)</td>
</tr>
<tr>
<td>Cause</td>
<td>Ecological consequence</td>
<td>Relative sensitivity</td>
<td></td>
</tr>
<tr>
<td>------------------------------</td>
<td>------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------</td>
<td>----------------------</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Continued river regulation &amp; water extraction</td>
<td>Continued river regulation &amp; water extraction plus worst case climate change</td>
</tr>
<tr>
<td>Reduced foraging and nesting habitat for birds</td>
<td>Mainly affecting freshwater-dependent species such as Eurasian Coot and Dusky Moorhen. Reductions in abundance of small forage fish could affect food supplies for terns (Common, Fairy, Little and Caspian terns).</td>
<td>Medium</td>
<td>High</td>
</tr>
<tr>
<td>Increased salinity</td>
<td>Potential for hypersaline waters to develop in adjacent wetlands/saltmarshes</td>
<td>Low</td>
<td>High</td>
</tr>
<tr>
<td></td>
<td>Lake Reeve and saltmarsh areas around the main lakes.</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Loss of fringing macrophytes and possible replacement with exotic taxa</td>
<td>High</td>
<td>High</td>
</tr>
<tr>
<td></td>
<td>Loss of fringing <em>Phragmites</em> reed beds has already occurred widely across the lakes.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Increased water clarity</td>
<td>Increased growth of microphyto-benthos</td>
<td>Uncertain</td>
<td>Uncertain</td>
</tr>
<tr>
<td></td>
<td>The magnitude of this affect is unclear.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
## Estuarine river reaches mega-habitat

<table>
<thead>
<tr>
<th>Cause</th>
<th>Ecological consequence</th>
<th>Continued river regulation &amp; water extraction</th>
<th>Continued river regulation &amp; water extraction plus worst case climate change</th>
</tr>
</thead>
<tbody>
<tr>
<td>Restricted upstream fish migration</td>
<td>Affecting mainly estuarine resident fish species such as River Garfish, Estuary Perch and Black Bream and some Goby species.</td>
<td>Medium</td>
<td>High</td>
</tr>
<tr>
<td>Lack of environmental triggers for fish spawning or movement</td>
<td></td>
<td>Medium</td>
<td>High</td>
</tr>
<tr>
<td>Reduced recruitment of fisheries to estuaries</td>
<td></td>
<td>Medium-High</td>
<td>High</td>
</tr>
<tr>
<td>Reduced foraging and nesting habitat for birds</td>
<td>Mainly affecting freshwater-dependent species such as Eurasian Coot and Dusky Moorhen. Reductions in abundance of small forage fish could affect food supplies for terns (Common, Fairy, Little and Caspian terns).</td>
<td>Medium</td>
<td>High</td>
</tr>
<tr>
<td>Cause</td>
<td>Ecological consequence</td>
<td>Relative sensitivity</td>
<td></td>
</tr>
<tr>
<td>-----------------------</td>
<td>----------------------------------------------------------------------------------------</td>
<td>----------------------</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Continued river</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>reg</td>
<td>water</td>
</tr>
<tr>
<td></td>
<td></td>
<td>extraction &amp;</td>
<td></td>
</tr>
<tr>
<td>Increased salinity</td>
<td>Seagrasses colonise upper reaches of estuary</td>
<td>Low</td>
<td>High</td>
</tr>
<tr>
<td></td>
<td>Loss of fringing macrophytes and possible replacement with exotic taxa</td>
<td>High</td>
<td>High</td>
</tr>
<tr>
<td></td>
<td>Loss of fringing <em>Phragmites</em> reed beds has already occurred widely across the lakes.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Increased salinity</td>
<td>Increased number (and diversity) of marine fish taxa in estuarine waters</td>
<td>Medium</td>
<td>High</td>
</tr>
<tr>
<td></td>
<td>If salinities increase, the abundance of marine estuarine-dependent and marine estuarine-opportunin fish species, as well as marine stragglers, will increase.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Increased salinity</td>
<td>Increased predation of fish by waterbirds or by other visual predators</td>
<td>Uncertain</td>
<td>Uncertain</td>
</tr>
<tr>
<td></td>
<td>The extent of this effect in the Gippsland Lakes is unclear.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Increased salinity</td>
<td>Increased growth of microphyto-benthos</td>
<td>Uncertain</td>
<td>Uncertain</td>
</tr>
<tr>
<td></td>
<td>The magnitude of this affect is unclear.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
### Main lakes mega-habitat

<table>
<thead>
<tr>
<th>Cause</th>
<th>Ecological consequence</th>
<th>Relative sensitivity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reduced annual discharge</td>
<td>Reduced seagrass habitat: Mainly shallow areas of lakes King and Victoria, Jones Bay may be affected. Losses may be offset by a more stable marine-type environment in the main lakes, which could be favourable to some seagrass species. Net response is uncertain.</td>
<td>Low (uncertain) &amp; Medium (uncertain)</td>
</tr>
<tr>
<td>Renstricted upstream fish migration</td>
<td>Affecting mainly estuarine resident fish species such as River Garfish, Estuary Perch and Black Bream and some Goby species.</td>
<td>Medium &amp; High</td>
</tr>
<tr>
<td>Reduced recruitment of fisheries to estuaries</td>
<td></td>
<td>Medium-High &amp; High</td>
</tr>
<tr>
<td>Reduced fisheries production (fin fish, bivalves, crustaceans)</td>
<td>The lakes are currently eutrophic and would likely continue to be so despite lower inflows, so the likelihood of this effect is uncertain.</td>
<td>Uncertain &amp; Uncertain</td>
</tr>
<tr>
<td>Cause</td>
<td>Ecological consequence</td>
<td>Relative sensitivity</td>
</tr>
<tr>
<td>-------</td>
<td>------------------------</td>
<td>----------------------</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Continued river</td>
</tr>
<tr>
<td></td>
<td></td>
<td>regulation &amp; water</td>
</tr>
<tr>
<td></td>
<td></td>
<td>extraction</td>
</tr>
<tr>
<td>Reduced foraging and nesting habitat for birds</td>
<td>Mainly affecting freshwater-dependent species such as Eurasian Coot and Dusky Moorhen. Reductions in abundance of small forage fish could affect food supplies for terns (Common, Fairy, Little and Caspian terns).</td>
<td>Medium</td>
</tr>
<tr>
<td>Altered water temperatures</td>
<td>The ecological effects of temperature change on aquatic habitats is unclear.</td>
<td>Uncertain</td>
</tr>
<tr>
<td>Increased salinity</td>
<td>Decline of some seagrass species (e.g. less salt-tolerant taxa)</td>
<td>Due to the maintenance of the entrance, salinities in the Main Lakes are not expected to rise beyond standard seawater (~35 g/L) which is well within the tolerance of most seagrass species in the lakes.</td>
</tr>
<tr>
<td></td>
<td>Loss of fringing macrophytes and possible replacement with exotic taxa</td>
<td>Loss of fringing <em>Phragmites</em> reed beds has already occurred widely across the lakes.</td>
</tr>
<tr>
<td></td>
<td>Reduced algal growth rates and increased herbivory</td>
<td>The likelihood of this phenomenon and its effect is unclear.</td>
</tr>
<tr>
<td>Cause</td>
<td>Ecological consequence</td>
<td>Relative sensitivity</td>
</tr>
<tr>
<td>-------</td>
<td>-----------------------</td>
<td>---------------------</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Continued river regulation &amp; water extraction</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Medium</td>
</tr>
<tr>
<td></td>
<td>Increased risk of invasion by noxious oceanic species (plant and animal)</td>
<td>Salinity increases will favour marine species over estuarine species. Given that there are some noxious marine species (e.g. Japanese Sea Star, Codium algae) established elsewhere on the Victorian coast, there is a significant risk of invasion.</td>
</tr>
<tr>
<td>Increased number (and diversity) of marine fish taxa in estuarine waters</td>
<td>If salinities increase, the abundance of marine estuarine-dependent and marine estuarine-opportunist fish species, as well as marine stragglers, will increase.</td>
<td>Medium</td>
</tr>
<tr>
<td>Altered sediment load and deposition</td>
<td>Altered seagrass distribution and condition</td>
<td>Possibly affecting Lake Wellington around the riverine inflows, Jones Bay and adjacent areas in Lake King. As sediment loads are mainly transported in flood events, the impact of this phenomenon is unclear.</td>
</tr>
<tr>
<td>Altered seagrass distribution and condition</td>
<td>Altered abundance of turf-forming algae (via both top-down and bottom-up impacts)</td>
<td></td>
</tr>
<tr>
<td>Decreased recruitment, growth and survival of macroalgae</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cause</td>
<td>Ecological consequence</td>
<td>Relative sensitivity</td>
</tr>
<tr>
<td>-------</td>
<td>------------------------</td>
<td>----------------------</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Continued river regulation &amp; water extraction</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Low</td>
</tr>
<tr>
<td>Altered abundance and diversity of meiofauna</td>
<td>The extent of this effect in the Gippsland Lakes is unclear.</td>
<td>Uncertain</td>
</tr>
<tr>
<td>Interference with filter-feeding macrofauna (e.g. mussels, oysters)</td>
<td>If average salinities increase, it can be expected that the depth distribution of seagrass species will increase around the margins of the current maximum depth contour.</td>
<td>Low</td>
</tr>
<tr>
<td>Increased water clarity</td>
<td>Increased predation of fish by waterbirds or by other visual predators</td>
<td>The magnitude of this affect is unclear.</td>
</tr>
<tr>
<td>Increased depth distributions of seagrasses</td>
<td>The extent of this effect in the Gippsland Lakes is unclear.</td>
<td>Uncertain</td>
</tr>
</tbody>
</table>

Figure 10 of this report shows the projected impact of the combination of climate change and catchment water use on gross salinity levels in the lakes. Under worst case climate change assumptions, freshwater inflows are unlikely to be sufficient to induce variable salinity in lakes Victoria and King and Jones Bay and the effect of the entrance will dominate. Lake Victoria, Lake King and Jones Bay are likely to move from their current estuarine condition to a predominantly marine condition.
4.2 Priorities for determining environmental water requirements

Ideally, an understanding of the freshwater requirements of the Gippsland Lakes system would be based on a detailed investigation of all spatial components. Given the size and complexity of the system and the variability in response to freshwater inflows, a pragmatic approach is recommended: the use of broad spatial priorities for the investigation of environmental water requirements.

The establishment of priority areas considers:

- the relative sensitivity of the mega-habitats to changes in freshwater inflows
- the importance of the ecological condition of different spatial components to the values of the lakes system
- areas of low knowledge and therefore potentially high risk
- providing protection to areas currently in relatively good ecological condition
- our ability to influence flow components that are deemed to be important. (For example, there are unlikely to be available management options to counteract a climate driven change in the frequency of large flood events.)

The resultant priorities provide a broad indication of the mega-habitats of greatest or immediate need for the proactive investigation of environmental water requirements. The ranking of individual wetlands, embayments or waterways within each mega-habitat needs to consider a broader range of factors which are outlined in chapter 5.
Fringing wetlands

Freshwater and variably saline fringing wetlands

It is clear that patterns of freshwater inflows from the inflowing rivers exert a dominant effect on the condition of freshwater and variably saline fringing wetlands. Some wetlands have already been studied in detail and knowledge of wetland functioning transferred from elsewhere reinforces the link from wetting and flushing flows to the quality and extent of vegetation and hence to the general health of the wetland. Through their characteristic vegetation and associated habitat and food production capabilities, these wetlands are known to make a crucial contribution to the ecological health of the lake system as a whole and to contribute to aesthetic and tourism values. They are an integral element of the listing of the Gippsland Lakes as a Ramsar site and support numerous JAMBA and CAMBA listed species. We can be confident in proposing that wetting and flushing flows for freshwater and variably saline wetlands are vitally important to the identified values of the Gippsland Lakes system. Freshwater and variably saline wetlands are at high risk from the adverse impacts of secondary salinisation and altered wetting and drying cycles, both of which are controlled directly by freshwater discharge. Sea level rise will also have an adverse impact.

Hypersaline wetlands

While freshwater inflows also influence the extent and condition of hypersaline wetlands, compared to the freshwater and variably saline wetlands the influence is expected to be less critical if they continue to experience episodic marine inundation. They are also often dependent on higher freshwater inflows that are likely to be less influenced by past or future management decisions. In comparison with the role played by freshwater and variably saline wetlands, the effect on hypersaline wetlands and their impact on the lakes system as a whole is expected to be less. For some specific sites that are hydrologically connected to smaller waterways or wetlands (e.g. parts of Lake Reeve and Victoria Lagoon) there may be localised undesirable impacts arising from altered patterns of freshwater inflow.

Main lakes

It is clear also that freshwater inflows contribute to the ecological condition of the main lakes, not only through their vital role in controlling the spatial and temporal variations in salinity (see Figures 7, 8 and 9) but also in providing fluxes of sediment, nutrients, organic matter and organisms as inputs to the lakes environment. While the dominant role of lake salinity on ecological condition is apparent, the relative importance of these other contributions is not well understood.

Deep lakes

As a consequence of the permanent entrance, the deep lakes – Lakes Victoria and King – are already permanently saline (to at least half the salinity of seawater) throughout their profile for much of the time. Stratification occurs when freshwater inflows displace saline water from the upper part of the profile and does not mix with the lower, saline water. A reduction in overall salinity will follow to the extent that mixing subsequently occurs. A reduction in the frequency, magnitude or duration of freshwater inflows will alter the salinity and stratification regime and would be expected to lead to higher salinity levels generally and a reduction in the severity and frequency of major stratification events. The ecological consequences of this change would be manifest as a shift toward fish and other aquatic species that favour marine environments over those with more freshwater or estuarine dependencies.
Changes in salinity regime in the deep lakes have probably also had an influence on the occurrence and species composition of algal blooms, but details are not well understood. It is known, however, that the species of algae that currently most commonly forms blooms, *Nodularia spumigena*, is well adapted to the brackish water environment that exists across much of the main lakes. Although increased salinity may lower the risk of bloom formation by *Nodularia*, conditions may simply be created that favour algal blooms by other, more oceanic taxa. The recent bloom of *Synechococcus* demonstrates our poor ability to forecast the incidence of algal blooms in the Gippsland Lakes and the role that altered environmental conditions undoubtedly play in bloom formation and maintenance.

Deterioration of shoreline vegetation is a longer term consequence of altered hydrologic and salinity regimes that probably commenced soon after the entrance was opened and is continuing to this day. Under climate change, further changes could be profound as the deep lakes become effectively an extension of the marine environment. With more moderate changes to inflow, such as from full licence development, the impact on the deep lakes is expected to be overwhelmed by the continuing influence of the entrance and, on the basis of current knowledge, further impacts would probably be small.

As a consequence, the relative importance of freshwater inflows in the deep lakes over the short term is postulated to be less than that for the other spatial components of the lakes system. The deep lakes are also dependent on higher flows that are likely to be less influenced by past or future management decisions. Whether the impact is limited over the longer term remains to be seen, as riverine discharge of fresh water controls not only obvious physico-chemical variables such as salinity but has a suite of more subtle effects on processes such as nutrient import and sediment loads. It may take decades for the ecological consequences of altered nutrient and sediment loads to become manifest, and if they do arise they may well be irreversible. Similar arguments can be mounted for a host of life-cycle issues, of which nothing is known for most taxa in the Gippsland Lakes.

**Shallow lakes**

Consequences of reduced freshwater inflows are expected to be greater for the shallow lakes – which include Lake Wellington and Jones Bay. Lake Wellington has already undergone a major change in state in the late 1960s, from a condition dominated by fresh, clear water with a macrophyte-covered bed and good fringing vegetation to the current condition which is characterised by a variably saline regime with the loss of all submerged plants, deteriorating shoreline vegetation and turbid water susceptible to episodic algal blooms. The exact trigger for this change in state is still debated, but increasing salinity associated with the entrance and reduced freshwater inflows are clearly implicated in the change from a desirable macrophyte-dominated system to a turbid, algal-dominated system of far lower ecological, social and economic value. Without a barrier preventing intrusion of salt water through the McLennan Straits, it is likely that the change in vegetation dominants in Lake Wellington is irreversible. Increasing salinity in Lake Wellington, which is directly related to the volume of freshwater inflows, can also adversely impact the quality of water entering its fringing wetlands, and is the major cause of their increasing salinisation.

The drastic change in the condition of Lake Wellington provides a salutary warning of the extent of change that can occur when a physical-biological tipping point is reached. It should also focus attention on Jones Bay as the other major shallow lake in the system. In fact Jones Bay is better connected to the deep lakes than is Lake Wellington and it has significantly different characteristics. Nevertheless its location on the landward side of the Mitchell silt jetties and adjacent to significant wetlands makes it both important and particularly vulnerable to changes in the flow characteristics of the Mitchell and Nicholson rivers. The potential physical and ecological consequences of such changes are unknown but of sufficient concern to classify determination of its freshwater requirements as important.
Estuarine river reaches

It is certain that the magnitude, frequency and duration of flows in the rivers contributing to the lakes is the primary factor in determining the salinity regime of the estuarine river reaches. In turn, changes in the salinity regime can have important ecological consequences including an impact on fringing vegetation and on the suitability of the estuarine reach for fauna habitat, particularly for fish breeding. The loss of fringing reed beds along the major rivers flowing into the Gippsland Lakes has been well studied, and increasing salinity is implicated as the single most important factor in the deterioration of this critical riparian zone. The lessening of nutrient interception and shoreline protection roles, increased bank erosion, and loss of valuable habitat are all consequences of the loss of fringing vegetation.

Of particular interest is the case when a halocline extends upstream from the lakes into the lower reaches of the river. It is speculated that the existence of a halocline in the vicinity of the river mouth may provide optimum conditions for breeding of Black Bream and perhaps other species. On the other hand, low river flows can allow a halocline to persist further upstream in the river with adverse impacts on bank vegetation and hence on the stability of the river bank. This can be particularly important where vegetation stabilises a natural levee as part of a silt jetty formation or as hydraulic control for a wetland complex. Upstream intrusion of the halocline can also adversely impact on the quality of water entering fringing wetlands. Because of the diverse and potentially serious consequences of movement of the halocline, the importance of investigating the freshwater inflow requirements of the estuarine reaches is classified as high.
4.3 Priorities under climate change

Climate change (see box on page 19, Section 2.4) is predicted to lead to:

- reduced rate and quantity of freshwater inflows to the lakes system
- increased water levels in the lakes in response to increased sea levels
- more frequent and more severe wildfire in the catchments leading to increased flooding and sediment and nutrient inputs followed by reduced catchment yield
- more frequent and more severe floods.

Sensitivity testing has shown that under an assumption of worst case climate change on top of current levels of extraction, the deep lakes are likely to become saline to the extent that they reflect marine conditions for most of the time. Even though the reduction in freshwater inflows is predicted to be of similar magnitude to that already experience through river regulation and diversions, the ecological consequences of the climate change reductions are likely to be more severe than current impacts because they will:

- significantly reduce water yield from all of the lakes’ catchments, rather than just the western rivers as at present
- will be in addition to already dramatic reductions in inflows to Lake Wellington from the Latrobe, Thomson and Macalister rivers
- be combined with predicted sea level rises and expected breaching of the outer barrier during storm surges.

Climate change therefore has the potential to exert an overwhelming influence on the future state of the Gippsland Lakes system. This potential influence has very significant ramifications for many of the important values of the lakes system, including its Ramsar values.

Under the worst case climate change scenario, estuarine habitats retreat out of the deep lakes and into the shallow lakes and the lower reaches of the inflowing rivers. This makes management of those freshwater inflows that maintain residual estuarine values in the shallow lakes and estuarine river reaches important not only for the values directly associated with those zones, but also to maintain the ecological, tourism and aesthetic values of the adjacent fringing

The impact of ‘worst case’ climate change is massive. It will change the way we think about managing natural resources. We will no longer be able to use our current notions of ‘naturalness’ as a template for management objectives. If we are to retain some of the values we assign to the lakes system and to meet responsibilities consistent with the lakes system’s Ramsar listing, natural resource managers will be required to make difficult management decisions, choosing to sacrifice some environmental, social and economic values in order to protect others; and using artificial means (such as flow regulators, pumps, barriers, barrages or earthworks) in combination with environmental flows, to preserve a selection of ‘natural’ values in the vulnerable areas. Managers will be expected to intervene in natural processes more than ever before. Yet while our understanding of the fundamental links between hydrology and ecology remains sparse, we have little to substantiate such important management decisions other than an individual’s or an organisation’s values and beliefs. If ever there was a rationale for better understanding the systems that we will be required to manage in future, then climate change is it!
wetlands. Management of wetlands that have important local recognition, and national and international significance (such as Dowd Morass, Heart Morass, Sale Common & Macleod Morass), becomes increasingly important and increasingly difficult under these conditions.

Freshwater inflows will play an important role in the future of the Gippsland Lakes system regardless of whether the long-term objectives of management are to protect existing values, or to manage a transition to a new future state. Environmental flows alone cannot offset the impacts of water regulation and extraction and climate change however.

4.4 Summary of priorities

A summary of the spatial priorities for determining environmental water requirements is presented in Table 10 and Figure 11.
### Table 10 Relative priority of the mega-habitats for the determination of environmental water requirements

<table>
<thead>
<tr>
<th>Mega-habitat</th>
<th>Priority</th>
<th>Comment</th>
<th>State of knowledge for high and very high priority areas</th>
</tr>
</thead>
<tbody>
<tr>
<td>Freshwater wetlands</td>
<td>Very high</td>
<td>Wetting flows and flushes are known to be vital to wetland condition. Wetland condition is a crucial contributor to the overall value of the lakes system. Ecologically important flows are in the range that is significantly affected by river regulation.</td>
<td>We understand the basic physical and ecological processes at work here and we know that the wetlands are vulnerable to future changes in inflows. Some investigation has already been initiated for the larger wetlands in the Latrobe system (Heart, Dowd and Clydebank morasses and Lake Coleman), but needs to be refined and expanded to include the remaining freshwater wetlands (e.g. Sale Common and the Long Waterhole wetlands). No work has been done for wetlands on the Mitchell (Macleod Morass), Tambo (Russells and Tambo River swamps) or Nicholson River (Bosses and Nebbor swamps), Tom Creek (Backwater Morass) or McLennan Straits (Morley Swamp, Lake Betsy, and Betsy’s Neighbour Lagoon).</td>
</tr>
<tr>
<td>Variably saline wetlands</td>
<td>Very high</td>
<td>Wetting flows and flushes are known to be vital to wetland condition. Wetland condition is a crucial contributor to the overall value of the lakes system. Ecologically important flows are in the range that is significantly affected by river regulation.</td>
<td>We understand the basic physical and ecological processes at work here and we know that the wetlands are vulnerable to future changes in inflows. Some investigation has already been initiated for the larger wetlands in the Latrobe system (Heart, Dowd and Clydebank morasses and Lake Coleman), but needs to be refined and expanded to include the remaining freshwater wetlands (e.g. Sale Common and the Long Waterhole wetlands). No work has been done for wetlands on the Mitchell (Macleod Morass), Tambo (Russells and Tambo River swamps) or Nicholson River (Bosses and Nebbor swamps), Tom Creek (Backwater Morass) or McLennan Straits (Morley Swamp, Lake Betsy, and Betsy’s Neighbour Lagoon).</td>
</tr>
<tr>
<td>Hypersaline wetlands</td>
<td>Moderate</td>
<td>Freshwater inflows are an important contributor to the condition of hypersaline wetlands but generally at a magnitude not significantly impacted by river regulation and diversion.</td>
<td></td>
</tr>
<tr>
<td>Main lakes</td>
<td>Deep lakes</td>
<td>Moderate</td>
<td>Salinity from the entrance dominates environmental condition. Except for step climate change, deep lakes are likely to be relatively insensitive to likely changes in inflows.</td>
</tr>
<tr>
<td>Shallow lakes: Jones Bay</td>
<td>High</td>
<td>The ecological condition of Jones Bay is vulnerable to change from changes in freshwater inflows. Jones Bay is in relatively good condition and is important to the value of the lakes system because it provides high quality fish and waterbird habitat.</td>
<td>Jones Bay is likely to be vulnerable to future changes in inflows, but very little is known about its physical or ecological functioning or its likely response to threats.</td>
</tr>
<tr>
<td>-------------------------</td>
<td>------</td>
<td>-------------------------------------------------------------------------------------------------</td>
<td>-------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Shallow lakes: other</td>
<td>Moderate</td>
<td>Lake Wellington is important to the condition of its fringing wetlands however the lake has undergone a significant change in state which diminishes its value in the overall lakes system. The change is thought to be irreversible without dramatic intervention. Salinity from the entrance dominates the environmental condition of the remaining shallow lakes (North Arm and Cunninghame Arm).</td>
<td></td>
</tr>
<tr>
<td>Estuarine reaches of rivers</td>
<td>High</td>
<td>The length and location of the halocline is dominated by freshwater flows. Length and location of the halocline are thought to be important for fish breeding and for condition of bank vegetation and hence stability of estuarine reach. The range of flows that are heavily impacted by river regulation and diversion have a strong physical and ecological influence on the estuarine river reaches.</td>
<td>The Latrobe, Avon, Mitchell, Tambo and Nicholson rivers’ estuaries have high values and are vulnerable to future changes in freshwater flows. The basic physical processes that determine estuary behaviour are understood but these have not been quantified for these estuaries and little is understood about the ecological response.</td>
</tr>
</tbody>
</table>
Figure 11 Schematic diagram showing the relative priority of the mega-habitats of the Gippsland Lakes system for the determination of environmental water requirements.
5 An approach to determining the environmental water requirements of the Gippsland Lakes system

The previous section proposes broad spatial priorities for the determination of the environmental water requirements of the lakes system based on a preliminary appraisal of the likely consequences of changes in freshwater inflows on ecological condition and the subsequent impact of those changes on the values of the Lakes. This chapter proposes an approach to determining environmental water requirements which enables an assessment of the consequences of flow apportionment decisions for these priority areas.

The existing cap on water extractions in the Gippsland Lakes catchments (see box on page 8, Section 1.1) was introduced as an expediency to limit further changes in inflows until the impact of flows on the social, economic and environmental values of the lakes system was better understood. The cap was based pragmatically on existing levels of use, with some allowance for minor increased water resources development in the eastern catchments. The cap is not founded in any explicit assessment of the relative values of impacts of water use or water restrictions on either environmental or consumptive use values.

Concern to protect the economic, social and environmental values of the lakes system (including wetlands and estuaries), together with ongoing threats to its values from climate change; and on-going demands for water resources development in the catchments, present an impetus for moving beyond the interim cap to provide a substantiated basis for future allocation and management of freshwater inflows to the lakes. The proposed way forward is to associate progressive management decisions about environmental flows (and consumptive water use) with a developing knowledge base about the Gippsland Lakes and the processes that support its values.

5.1 The approach

The approach described here proposes that management decisions about apportionment of water resources be based, as far as possible, on an informed assessment of the relative impacts of the decision on economic, social and environmental values.

Management decisions about water apportionment often have to be made in the absence of adequate

Methods for determining the environmental flow requirements of rivers and estuaries are numerous and varied. Regardless of the detail of their approach or their level of sophistication, all methods are ultimately based on a deduced or inferred relationship between hydrologic input and ecological response – an ecological response model. Understanding the dominant characteristics of this relationship – which aspects of the flow regime are most closely related to which aspects of ecological response, the broad shape of the relationship, the location of thresholds within that relationship – is the fundamental requirement for successful application of any of the methods. The better this relationship is understood, the more robust the results of applying the method will be.

The Gippsland Lakes system has been shown to be a complex environment, where physical processes are often not quantified and ecological response models are in many cases hypothetical at best. The importance of selecting a standardised approach to environmental flow assessments is therefore secondary to the need to improve our understanding of the dominant characteristics of the hydrologic-ecological relationships in the critical components of the system.
information. In the case of the Gippsland Lakes system, the effect of past water resources apportionment decisions on the values of the Lakes has been investigated to some extent as reported here, but the effect of possible future management decisions cannot be predicted with any confidence. The conceptual approach outlined here endeavours to deal with this shortcoming. In particular, the progressive and iterative nature of the approach allows preliminary management decisions to be proposed (in the form of management objectives) on the basis of available knowledge; using those decisions to target knowledge gaps and in turn to test and refine the decisions through time.

This approach recognises that environmental water “requirements” are inexorably linked to decisions about management objectives which, more often than not, will involve some form of trade-off. Good decisions will be well informed about the consequences of the compromises that are contemplated. For values related to the environment, this requires an understanding of the shape of the response function, not just knowledge of a single point. Good management decisions will also reflect the reality that the knowledge on which they are based will develop through time.

Understanding social, economic and environmental consequences is a prerequisite for rational management decisions about flow apportionment. The recommended approach recognises that for effective progress to be achieved, the setting of management objectives and understanding of environmental water requirements must advance in consort. The approach must also accommodate uncertainty and change in key drivers (climate change for instance).

Key success factors for the approach are therefore:

- **It is iterative**: recognising that initial management decisions demarcate areas of knowledge to be developed, and once developed, the knowledge allows decisions to be tested and refined. Iteration allows initial decisions to be made within broad confidence bands, and then, where justified by the outcomes, progressively refined with increasing knowledge;

- **It is targeted**: knowledge is built to specifically address priority knowledge gaps; and
• *It is progressive:* answers evolve and are refined through time in response to emerging priorities and improving knowledge.

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**Environmental water requirements and flow management recommendations**

The phrase *environmental water requirement* suggests the determination of a definitive flow regime which must be provided if the needs of the Gippsland Lakes ecosystems are to be met now and into the future. The reality is however that such an investigation currently would:

1. be based on achieving a level of ecological condition (representing a level of ecological risk) that is usually poorly defined but is implicitly considered acceptable under current circumstances
2. rely on an existing knowledge of ecological response to flow that is generally inadequate given the potential magnitude of the impacts on environmental condition and on consumptive use
3. employ a limited understanding of how ecological condition affects the social and environmental values of the system.

The appropriateness of ecological objectives and the strength of the underpinning knowledge base are expected to change over time under the influence of consumptive water demands, climate change and improving knowledge. The output from an environmental water requirements investigation is rarely definitive. Rather, it represents the best estimate of achieving a particular set of ecological conditions at a given point in time.

The recommended approach to determining environmental water requirements for the Gippsland Lakes system recognises that flow management objectives depend on knowledge of impacts on environmental and consumptive use values and that knowledge will continue to develop in response to the focus that the management objectives bring. Rather than an *environmental flow requirement*, which might focus knowledge building efforts on a part of the response curve that is ultimately irrelevant, the phrase *flow management recommendation* has been used to describe the output from the recommended approach.

The *flow management recommendation* is the flow regime which will maintain the system at a level of ecological risk adopted as appropriate to the situation. The recommended approach deliberately places importance on providing information about the level of risk associated with different water management options, rather than simply recommending a single definitive regime to provide a single outcome. The flow management recommendations are a collection of ‘environmental guidelines’ that will directly inform trade-off discussions. Where current understanding is poor, flow management recommendations may have to accommodate broad error bands until improved knowledge is generated from targeted investigations.

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5.2 **Implementing the approach**

The proposed approach is presented in Figure 12. The approach is then explained by listing the steps in its implementation. Note that the graphics provide the link between the framework and the steps.
Figure 12 Framework to describe progressive development of flow management recommendations for the Gippsland Lakes
### Steps in implementing the approach

#### Priority areas
The scoping study has used a preliminary assessment of the links from freshwater inflows to ecological condition and hence to economic, social and environmental values to identify priority areas where freshwater inflows have an important influence on the future of the lakes (i.e. freshwater and variably saline fringing wetlands, estuarine river reaches and Jones Bay).

These are areas where the preliminary analysis suggests a vulnerability to changes in freshwater inflows that justifies proactive investigation of flow requirements as a pre-emptive measure.

#### Key drivers
The key drivers of flow related impacts on the Lakes are:
- existing and likely future demands for water extraction
- the impact of climate change
- the on-going effects of the permanent entrance.

Changes in these drivers can help assign urgency rankings between priority areas, or elevate other areas for consideration and can justify reactive investigation of flow requirements.

#### Rank priority areas to investigate
A mechanism is required to reach agreement on ranking of areas for investigation. This mechanism must bridge the social and environmental priorities established in the scoping study with the evolving short and long term management imperatives around water resources development in the catchments.

A further action here is to negotiate responsibility for setting management objectives that combine consumptive use and environmental aspirations, and who therefore drives this process forward.

#### Preliminary management objectives
In areas identified for detailed investigation, the preliminary understanding of values and threats (from the scoping study), together with an evaluation of consumptive use demands and drivers, helps to propose preliminary management objectives.

(An example of a preliminary management objective to be tested might be “water will be provided to maintain and improve the aesthetic and recreational value of Macleod Morass”. This objective would not sit in isolation but would be accompanied by other objectives dealing with, amongst other things, maintaining consumptive use values.)

Preliminary management objectives must be set in the context of the uncertainty that prevails and to be precautionary, must provide for generous margins of error around consequences and risks. Future iterations, based on better knowledge, may move to objectives that are more precise.
Driven by the stated management objectives, this step is to develop a targeted understanding of the physical and ecological processes that dominate ecosystem behaviour. The emphasis is on those aspects of physical and ecological functioning that are revealed as most important for their interaction.

As a first pass, this need not involve detailed quantitative analyses and/or modelling. The first pass can be more of a sensitivity check, applying similar techniques to those used in this scoping study but with a specific geographic and management focus at a finer spatial scale. This is to reveal the level of interrelationship between physical and ecological conditions and the consequences for the values addressed by the management objectives.

**Hydrology and hydraulics**

For the hydrologic investigations, effort should be targeted on those processes that are likely to dominate ecological response. This will help drive the investigation of ecological processes which will in turn allow a refocus of the hydrologic investigations and so on. An appropriate level of detail for the hydrologic analyses will be set by the ability of the ecological analyses to discriminate different outcomes.

**Ecological functioning**

In general, quantitative assessments of the physical processes are likely to be possible to some extent – sufficient data and understanding exists so that hydrology and hydraulics can be quantified – but, accurate depiction of ecological functioning is likely to be more difficult to substantiate. The difficulty arises in part from a poor understanding of what functions dominate the current ecological trajectory – let alone how that might change in future. Close interaction with the concurrent hydrologic analyses will help focus attention on the functions, locations, water levels and time periods that are most important to current and future ecological trajectories. Data from existing biotic surveys and targeted biological or physical (topographical) mapping, or both, are sources of information that would be employed in the ecological analysis.

The above hydrological and ecological considerations result in a preliminary ecological response "model". This needs to be sufficiently well developed to link key ecological values to characteristics of the flow regime providing an indication of the shape of the response function (not just a single point) and the location of any significant thresholds.

While the hydrological side of the "model" may be quantitative, the ecological response is likely to be expressed qualitatively at first.

It is important to understand the degree of uncertainty associated with this ecological response model because this will be relevant when the management objectives are revisited. i.e. if we are very unsure about the response, then objectives may need to be set with a wide precautionary error band.
Flow management recomm. Using the ecological response “model”, determine and quantify as far as possible those aspects of the flow regime that are important to the management objectives.

The flow management recommendation is not expected to be a single recommendation, but will include advice on no-go parts of the flow regime and the spectrum of risk associated with other parts of the flow regime.

Various methods are available to assist this step and different methods may apply during different iterations of this approach. The Appendix gives guidance for selecting an appropriate method.

First iteration Three things can now be fed back to the start of the process:

- A preliminary indication of the magnitude, duration, frequency and seasonality of flows required to meet management objectives
- A preliminary assessment of the sensitivity of the objectives to changes in flow regime, together with the likely location of thresholds in the flow-ecology relationships
- An indication of the uncertainty surrounding the information.

Review management objective The management objective would now be reviewed in the light of this information. Three broad outcomes are possible:

1. It can be concluded with reasonable certainty that all objectives can be met and therefore no further iteration is needed.
2. There is a reasonable possibility that some objectives cannot be met and the degree of impact, and the level of uncertainty surrounding it, justify a more detailed pass through the process to reduce the uncertainty in the flow recommendations.
3. It can be concluded with reasonable certainty that some objectives will not be met and therefore revised objectives are required that compromise either consumptive or social/environmental values or both. A further iteration through the process is then likely to be required to refine the consequences or test the new objectives.

Under outcomes 2 or 3 above, second and subsequent passes through the process will target specific hydrologic, hydraulic and ecological knowledge in response to management objectives as they are refined. Where justified, this will lead to detailed physical process modelling and ecological investigations and a progressive increase in understanding of the physical and ecological functioning of the system.

At each step, the endeavour is to build credibility and reliability into the process by moving beyond our current reliance on “belief” based decisions (preconceived ideas of expected system behaviour) to decisions that are substantiated by a level of knowledge and understanding that is commensurate with the importance of the decision being made.

Increasing knowledge will improve the credibility of management decisions and improve the acceptance of outcomes.
Integrative approach

The framework describes a knowledge-based approach to management. Building this knowledge base is an iterative process; targeted by management objectives that are in themselves guided by an appreciation of the sensitivity of the various components of the lakes system to changes in freshwater inflows and recognition of the importance of each component to the values of the lakes.

Care is required to ensure that this focussed approach does not overlook system-wide responses that might also be at play. The process requires coordinated knowledge building, progressively assembling expertise in the most relevant physical, chemical and biological processes in the priority areas, while not ignoring implications of new knowledge for the rest of the main lakes, wetlands and estuarine reaches of the system. This requirement suggests an institutional arrangement that integrates knowledge building and management; systematically generating and consolidating the most relevant knowledge on lake behaviour across the system and providing this knowledge to aid management decisions.

5.3 Applying the proposed approach to the Gippsland Lakes system

The following two examples illustrate how the proposed iterative, knowledge-based approach could apply to the Gippsland Lakes system either proactively to develop desirable environmental flow regimes for the priority areas that have already been identified or reactively in response to proposals for water resources development.

Note that the background graphics in the left column relate to the approach illustrated in figure 12 (section 5.2).

<table>
<thead>
<tr>
<th>Example. A priority area in the eastern lakes - Mitchell River Estuarine Reach</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Social and Environmental values</strong></td>
</tr>
<tr>
<td>The Mitchell River estuary between Bairnsdale and Jones Bay is highly modified, however it retains significant environmental and social values. It is a Heritage River, has importance for native fish, including providing habitat for the nationally vulnerable Australian Grayling, and is a very popular reach for recreational fishing. It is identified as an iconic river in the Victorian River Health Strategy, and its silt jetties which form the boundary between Jones Bay and Lake King are of international geomorphological significance.</td>
</tr>
<tr>
<td>Estuary condition and behaviour is closely linked to the condition of Macleod Morass which fringes the lower Mitchell River and is one of the few remaining freshwater wetlands in the Gippsland Lakes system. It provides important habitat for aquatic and riparian vegetation communities, as well as wetland wildlife including waterbirds. Duck hunting is a popular recreational pursuit undertaken in the morass.</td>
</tr>
<tr>
<td>Jones Bay on the northern tip of Lake King is a shallow lake formed by the westerly extension of the Mitchell River silt jetties. It is part of the Gippsland Lakes Ramsar site, and is an area of particularly high waterbird diversity. It</td>
</tr>
</tbody>
</table>
also supports significant stands of seagrass and invertebrate and fish communities. These are priority areas for determination of environmental water requirements because of their significant values and relatively high sensitivity to flow changes within the range that management can influence.

**Other key drivers**

Consumptive water use currently has relatively little impact on freshwater inflows into this area, except during the summer/autumn period when low flows can be significantly affected.

There is an interim cap on the allocation of surface water from the catchments that flow into Lake King (existing entitlements plus 2,000 ML/yr). There are two existing consumptive water use pressures on the Mitchell River which are both within the existing cap:

1. East Gippsland Water proposes to transfer their existing entitlements from the Nicholson and Tambo rivers to the Mitchell River (about 2,900 ML/yr). An environmental flow study for the Mitchell River is currently underway to inform the development of suitable extraction rules to be applied to this new volume, based on the values of the freshwater reaches of the river. The estuarine reach and downstream habitats are not included in the study because they are part of the study area for this scoping study.

2. Existing licence holders are exploring options to increase the reliability of supply under their existing licences via some form of water storage. Their favoured option is a tributary dam and downstream delivery of water via the river.

Vegetation re-growth following fire is likely to significantly affect water yield from all catchments. Reductions in inflows due to climate change are likely to be significant. Salt water intrusion will penetrate further into the area due to a combination of reduced inflow and sea level rise. As a result, significant changes to geomorphic features could occur, in addition to salinity increases.

Physical infrastructure is currently used to inhibit the intrusion of salt water up the Mitchell River and into McLeod Morass. There is a need to examine the future role for these types of works.

**Preliminary management objective**

In the first instance, management objectives for this zone would focus on retention of those key social and environmental values that have made it a priority area in this scoping study, e.g. value for fish spawning, value for recreation, etc. In this case, initial objectives would probably also set out to accommodate existing patterns of consumptive use and the new consumptive use demands mentioned above.

**Hydrology and hydraulics**

In the first pass, effort should be targeted on those processes that are likely to dominate ecological response.

Attention is likely to focus on developing and communicating a semi-
quantitative understanding of the dynamics of the estuary and the impact of freshwater inflows on halocline movement and its persistence at various locations. This will initially involve compilation and interpretation of hydrologic, hydraulic and bathymetric data and may involve some simple modelling. Note however that limitations on understanding ecological processes will probably mean that there is little point developing the hydrologic information too far at this stage.

The focus of the hydrologic investigation is refined as understanding of the ecological functioning is developed and communicated.

<table>
<thead>
<tr>
<th>Ecological functioning</th>
</tr>
</thead>
<tbody>
<tr>
<td>The ecological functioning of the estuary is likely to be more difficult to substantiate. The difficulty arises from the need to understand what functions dominate the current ecological trajectory and how that may change in future. In the first pass, data from existing biotic surveys would be collated and interpreted. Targeted biological and physical habitat mapping is also required. Close interaction with the concurrent hydrologic analyses will help focus attention on the functions, locations, water levels and time periods that are most important to current and future ecological trajectories. For example, the analysis should address whether loss of bank vegetation is likely to result from changes in halocline dynamics and whether this is likely to have important ecological ramifications.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Ecological response model</th>
</tr>
</thead>
<tbody>
<tr>
<td>The above hydrological and ecological considerations result in preliminary ecological response “models”. This needs to be sufficiently well developed to link key ecological values to characteristics of the flow regime.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Flow management recomm.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Using the ecological response “model”, develop a recommendation for the flows that would be required to meet the management objective. In this case, the objective is to maintain ecological values while allowing some flow extraction so the appropriate method would be top down – setting out to describe the impact of existing and possible future extractions on the values of the estuary (see Appendix).</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>First iteration</th>
</tr>
</thead>
<tbody>
<tr>
<td>Three things can now be fed back to the start of the process:</td>
</tr>
<tr>
<td>• A preliminary indication of the magnitude, duration, frequency and seasonality of flows required to meet management objectives</td>
</tr>
<tr>
<td>• A preliminary assessment of the sensitivity of the objectives to changes in flow regime, together with the likely location of thresholds in the flow-ecology relationships</td>
</tr>
<tr>
<td>• An indication of the uncertainty surrounding the information.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Review management objective</th>
</tr>
</thead>
<tbody>
<tr>
<td>The management objective would now be reviewed in the light of this information and a further iteration undertaken to refine aspects of the assessment if justified.</td>
</tr>
</tbody>
</table>
### Example. A priority area in the western lakes - lower Latrobe River wetlands

The wetlands along the lower Latrobe River downstream of its confluence with the Thomson are: Sale Common and Heart Morass on the northern floodplain, and the Long Waterhole wetlands and Dowd Morass on the southern floodplain.

Sale Common and the wetlands in the vicinity of the Long Waterhole are the largest area of freshwater wetlands remaining in the Gippsland Lakes system. Sale Common is one of the few wetlands in which game hunting is prohibited. Sale Common, Dowd Morass and part of Heart Morass are part of the Gippsland Lakes Ramsar site.

The lower Latrobe wetlands provide important habitat for aquatic and riparian vegetation communities, as well as wetland wildlife including waterbirds. Fishing and duck hunting are popular recreational pursuit undertaken in Dowd and Heart Morasses.

The ecological condition of the lower Latrobe wetlands is influenced by the quality and quantity of flow in the lower Latrobe River estuary. This stretch of the river has good remnant riparian vegetation and is a very popular reach for recreational fishing and boating.

Lake Wellington, at the western end of the Gippsland Lakes system is a highly modified lake. Nevertheless it is a valued boating destination and important habitat for waterbirds during calm weather conditions.

These are priority areas for determination of environmental water requirements because of their significant values and relatively high sensitivity to flow changes within the range that management can influence.

### Social and Environmental values

- Sale Common and Heart Morass: Important habitat for aquatic and riparian vegetation communities, as well as wetland wildlife including waterbirds.
- Lower Latrobe wetlands: Provide important habitat for aquatic and riparian vegetation communities, as well as wetland wildlife including waterbirds.
- Lake Wellington: Highly modified lake, valued boating destination and important habitat for waterbirds.

### Other key drivers

- All components of the flow regime except major floods are significantly impacted by river regulation, diversions, and a drying climate in the Latrobe and Thomson basins.
- Surface water use from all catchments is capped. Water recovery for the environment is being undertaken in the Thomson basin based on the results of environmental flow studies for the Thomson and Macalister Rivers. Government is currently considering the formal allocation of water to the Latrobe River based on environmental flow investigations.
- Vegetation re-growth following fire is likely to significantly affect water yield from the Thomson basin. Reductions in inflows due to climate change are likely to be significant. Salt water intrusion will penetrate further into the lower river reaches due to a combination of reduced inflow and sea level rise.
- Physical infrastructure is currently used to facilitate water management in some wetlands. Examining the future role for these types of works may be part of management options as they are refined.
In the first instance, the competing environmental and consumptive use aspirations are to be enunciated. Management objectives for each of the lower Latrobe wetlands would be those defined by the respective wetland managers, which focus on retention of those key social and environmental values that have made them a priority area in this scoping study; e.g. value for waterbirds, characteristic wetland vegetation communities, value for recreation, etc. Consumptive use objectives will be stated in terms of existing use. In subsequent iterations, the implications of a range of possible changes to consumptive use could be explored along with the consequences for the condition of wetlands.

In the first pass, effort should be targeted on those processes that are likely to dominate ecological response such as river flows required to inundate and flush each wetland, spatial and temporal patterns of water depth and salinity in wetlands over time.

Quantitative water balance models already exist for Heart Morass and Dowd Morass. These models can be used in conjunction with knowledge of ecological responses to water regimes to determine the inflows required to achieve optimal physical habitat conditions, to assess the ecological impact of inflow changes and/or to explore the influence of physical infrastructure options to enhance water delivery. The existing models for Dowd and Heart Morass would logically be updated using more recently available data (including topographic (LiDAR), river flow, lake and wetland water level and salinity data) to improve certainty in existing estimates of wetland inflow thresholds and the spatial and temporal patterns in water regimes under different inflow conditions. It is justified to invest resources in updating these models as the ecological response of wetland vegetation communities to changes in wetland water regime is relatively well understood and useful additional data is readily available. Priority would also be placed on building a water balance model for the Sale Common given its status as one of the few remaining freshwater wetlands in the Gippsland Lakes system in the public estate.

The focus and detail of the hydrologic investigation is refined as understanding of the ecological functioning is developed and communicated.

Vegetation mapping is available for Sale Common, Dowd and Heart Morasses. This spatially-based ecological information would be used in conjunction with current knowledge of the physical habitat requirements of particular vegetation communities/species to interpret the ecological response to changes in the pattern of inundation and water quality produced by the quantitative models.

Close interaction with the concurrent hydrologic analyses will help focus attention on the functions, locations, water levels, water quality and time periods that are most important to current and future ecological trajectories. For example, the analysis should address whether loss of extensive areas...
of Swamp Paperbark stands is likely to result from changes in the quality or pattern of wetland water regimes and whether this is likely to have important ecological ramifications.

The above hydrological and ecological considerations result in preliminary ecological response “models”. These need to be sufficiently well developed to link key ecological values to characteristics of the inflow regime. This step quantifies the shape of the ecological response model in the area of interest.

Using the ecological response “model”, develop a recommendation for the flows that would be required to meet the management objective – the important characteristics of the wetland water regime, and the stream flow characteristics required to achieve this. In this case, it is likely that this will involve restoring parts of the flow regime so the appropriate method would be bottom up (see Appendix). Although a scenario based ‘top-down’ method might also be applicable because an assessment of the ecological response to pre-defined inflow changes is also required (see Appendix).

Three things can now be fed back to the start of the process:
- A preliminary indication of the magnitude, duration, frequency and seasonality of flows required to meet management objectives,
- A preliminary assessment of the sensitivity of the objectives to changes in flow regime, together with the likely location of thresholds in the flow-ecology relationships
- An indication of the uncertainty surrounding the information.

In this case it is almost certain that environmental and consumptive use aspirations cannot be readily achieved. So the first iteration can be rapid, serving to narrow the band for more detailed consideration. Management objectives would now be reviewed in the light of the knowledge of flow implications, seeking areas of compromise for evaluation in the next iteration (and so on). The management option of physical works\(^2\) or the possibility of offsets may be introduced during the iterations.

\(^2\) For example, inflows to fringing wetlands can be controlled by flow regulators and pumps, salinity could be controlled by barriers or barrages (a barrier in McLennan Straits has been proposed to control salinity in Lake Wellington), and breaches in barrier dunes caused by storm surges with sea level rise or flooding could be closed by various means (e.g. sand dredging, structural reinforcement).
5.4 Suitability of the approach

The approach described in this chapter is designed to be applicable and responsive to the immediate and longer term needs of natural resource managers. It will enable existing government commitments to be fulfilled (Our Water Our Future (DSE 2004) and the Central Region Sustainable Water Strategy (DSE 2006)), and a timely contribution to be made to the development of the Gippsland Region Sustainable Water Strategy.

The approach includes some important features which aim to gradually improve decisions, over time, regarding water allocation and management in the catchments of the Gippsland Lakes.

Relationship to the broader decision making process

The approach explicitly incorporates the iterative relationship between the development of flow management recommendations and decisions about water allocation and management. This is a subtle but important inclusion because the development of environmental flow recommendations, and ultimately environmental water reserves, is not independent of, but informs and is informed by, these deliberations.

Gradual evolution of understanding

The approach acknowledges the need to respond to management pressures by pragmatically and incrementally building the knowledge base relative to the level of risk posed, thereby allowing ecological understanding and management decisions to evolve together in a timely fashion. The alternative and traditional approach: to develop the underpinning physical and ecological knowledge to a level which will inform a wide range of management questions, is not feasible for the Gippsland Lakes system for reasons of spatial scale, resources and time.

Application to the Gippsland Sustainable Water Strategy

Although the approach is progressive and iterative, it can be used to provide short term input to the review of interim water use caps during the development of the Gippsland Region Sustainable Water Strategy.

The qualitative flow-ecology relationships and indicative quantitative flow thresholds summarised in this report could be used in a rapid preliminary assessment of the consequences of water allocation or management scenarios for the development of the Gippsland Region Sustainable Water Strategy. Given the low knowledge situation and short response time, the most sensible method to employ would be to establish a panel of relevant experts to provide their considered opinion on the likely ecological risks and/or benefits associated with a range of scenarios. The outputs from such a process are largely “belief” based and would necessarily be highly uncertain, but would provide the best indication currently possible of the environmental implications of any proposed inflow changes.

In the absence of specific water development pressures, there is justification to maintain the existing water use caps on the catchments of the Gippsland Lakes given the very high values of the lakes system and their reliance on freshwater inflows.
Glossary

benthic habitat Habitat on the bottom of a river, lake, or seabed. Commonly used in reference to the organisms that live on the bottom of such waterbodies.

bioavailability Refers to a substance that is in a form that is useable by organisms. Typically used in reference to chemical nutrients.

biofilm The film of living organisms, such as algae, fungi and bacteria that form a film over most underwater surfaces.

biota Living organisms whether they be plants or animals.

emergent macrophytes Aquatic plants that project their stems or leaves above the water surface (e.g. reeds, lilies).

emergent vegetation

environmental water requirement The flow regime needed to sustain the ecological values of a water-dependent ecosystem at a low level of risk

epifauna The community of (mostly small) invertebrate animals that live on the surfaces of submerged aquatic vegetation.

infauna The community of (mostly small) invertebrate animals that live within sandy and muddy aquatic habitats.

GIS Geographical information system, a form of computer-based mapping.

halocline A strong, vertical salinity gradient in a water body.

herbivory The dietary mode of an animal that consumes only plants.

macroalgae Species of algae that are clearly visible to the naked eye and ranging in size from small filaments to large seaweeds.

macrofauna Animals visible to the naked eye. Typically refers to larger marine invertebrate species such as starfish, crayfish and jellyfish.

macrophytes Aquatic plants that are not algae. Typically used in reference to larger submerged or emergent plants that grow in fresh water.

meiofauna Animals ranging in size from approximately 0.1 mm to 1 mm that live within the sediments, the size class of transition from micro to macrofauna.
<table>
<thead>
<tr>
<th>Term</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>microphytobenthos</td>
<td>Films of microscopic algae that live on the bottom of shallow lakes and shallow marine habitats and use sunlight and nutrients from the water and sediments to grow.</td>
</tr>
<tr>
<td>micro-topography</td>
<td>Precise detailed study of the surface features of a region including small-scale hillocks, depressions and gullies.</td>
</tr>
<tr>
<td>pelagic</td>
<td>Open water habitat or actively swimming</td>
</tr>
<tr>
<td>phytoplankton</td>
<td>Tiny plants, usually microscopic, that drift in the water column of lakes and oceans and use nutrients from the water and sunlight to grow.</td>
</tr>
<tr>
<td>residence time</td>
<td>The average amount of time water resides in a lake or wetland.</td>
</tr>
<tr>
<td>salt wedge</td>
<td>A wedge-shaped intrusion of salty ocean water into an estuary or river. It slopes downward in the upstream direction and salinity declines with depth.</td>
</tr>
<tr>
<td>step climate change</td>
<td>A marked and sudden change in climatic conditions in southeastern Australia since 1997, particularly reduced rainfall, as reflected in river flows.</td>
</tr>
<tr>
<td>taxa</td>
<td>A general term describing groups of related organisms.</td>
</tr>
<tr>
<td>water column</td>
<td>A general term used to describe the water overlaying the bed of a lake or wetland.</td>
</tr>
</tbody>
</table>
Photo credits

Cover photo unknown

Photo 1 unknown

Photo 2 unknown

Photo 3 Chris Holmes, Parks Victoria

Photo 4 Chris Holmes, Parks Victoria

Photo 5 Paul Boon, Dodo Environmental

Photos 6 to 8 Sean Phillipson, East Gippsland Catchment Management Authority
References


## Appendix

### Selection of environmental flow methods

There are a number of methods for determining environmental water requirements that have been used in Australia and internationally. They can be categorised into “top down” and “bottom up” methods as summarised below.

<table>
<thead>
<tr>
<th></th>
<th>Bottom-up</th>
<th>Top-down</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Description</strong></td>
<td>Bottom-up approaches aim to construct an environmental flow regime by accumulating inflow components of known ecological importance.</td>
<td>Top-down approaches aim to assess what will happen to an ecosystem if a change is made to the freshwater inflow regime.</td>
</tr>
<tr>
<td><strong>Basis for determination of the environmental water requirement</strong></td>
<td>The environmental water requirement is the flow regime required to reach a pre-determined environmental objective or target ecological condition.</td>
<td>The environmental water requirement is the flow regime which will maintain the system at an acceptable level of ecological risk.</td>
</tr>
<tr>
<td><strong>Advantage</strong></td>
<td>The result is strongly linked to specific values.</td>
<td>Produce information to directly inform trade-off discussions.</td>
</tr>
<tr>
<td><strong>Disadvantage</strong></td>
<td>Quantifying the flow required to achieve a defined environmental target can be difficult to achieve with reasonable certainty</td>
<td>The output does not represent a definitive volume of required water. Rather, it will produce a range of scenarios of volume, frequency, timing and duration, with different levels of associated environmental risk.</td>
</tr>
<tr>
<td><strong>Underpinning question</strong></td>
<td>Can ecosystem health be improved by restoring important characteristics of the natural flow regime?</td>
<td>How much can a river’s flow regime be changed before unacceptable ecological changes occur?</td>
</tr>
<tr>
<td><strong>Suitable application</strong></td>
<td>Flow restoration*</td>
<td>Flow protection</td>
</tr>
<tr>
<td><strong>Example methods</strong></td>
<td>FLOWS (Victoria), Building Block Method (South Africa) Flow Events Method (Victoria)</td>
<td>Sustainable Diversion Limits (Victoria), DRIFT (South Africa), Benchmarking (Queensland), ELOHA (international).</td>
</tr>
</tbody>
</table>

* Building block approaches can be used to build up a flow regime for one or many target environmental conditions. This can be done for flow restoration or protection purposes, although the former is the predominant application.
The Scoping Study establishes the freshwater and variably saline fringing wetlands, estuarine river reaches and Jones Bay as priorities for development of environmental water requirements. There is considerable variation in environmental water issues across the Gippsland Lakes system, and therefore between the individual components of the priority areas. This has implications for the type of method that is best suited to the determination of the environmental water requirements of different components of the Gippsland Lakes system. A broad assessment of the most suitable type of method for particular components of the Gippsland Lakes system is presented below.

<table>
<thead>
<tr>
<th>Spatial component / habitat</th>
<th>Overview of environmental water issues</th>
<th>Key underlying question</th>
<th>Most suitable method</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Lake Wellington area (Inflowing waterways: Latrobe, Thomson, Avon and Perry Rivers)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Estuarine river reaches</td>
<td>Freshwater inflows are significantly impacted by river regulation, diversions, and a drying climate. All but flood flows are impacted in the Latrobe and Thomson basins. Impact in Avon catchment is primarily on low flows. Surface water use from all catchments is capped. Water recovery for the environment is being undertaken in the Thomson basin based on the results of environmental flow studies for the Thomson and Macalister Rivers. Government is currently considering the formal allocation of water to the Latrobe River based on its environmental flow study and subsequent investigations. Vegetation re-growth following fire is likely to significantly affect water yield from the Thomson basin and Avon catchment. Reductions in inflows due to climate change are likely to be significant. Salt water intrusion will penetrate further into the area due to a combination of reduced inflow and sea level rise. Physical infrastructure is currently used to facilitate water management in some wetlands. There is a need to examine the future role for these types of works.</td>
<td>Flow restoration: Can ecosystem health be improved by restoring important characteristics of the natural flow regime?</td>
<td>Bottom-up&lt;sup&gt;1&lt;/sup&gt;</td>
</tr>
<tr>
<td>Freshwater wetland</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Variably saline wetlands</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Lake Victoria area (Inflowing waterways: McLennan Straits and various small creeks)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Variably saline wetlands</td>
<td>The issues described above for Lake Wellington area are also relevant to Lake Victoria area due to the inter-connection with McLennan Straits. The water regimes of wetlands adjacent to</td>
<td>Flow restoration: Can ecosystem health be improved by</td>
<td>Bottom-up&lt;sup&gt;1&lt;/sup&gt;</td>
</tr>
</tbody>
</table>
McLennan Straits are primarily influenced by the presence of artificial channels permanently connecting these water bodies. There is potential to explore the use of physical infrastructure to manage water regimes. Harvesting of surface water runoff in small farm dams and changing rainfall patterns are the major impacts on freshwater flows in Tom Creek which is an important water source for one of the variably saline wetlands in the Lake Victoria area (Backwater Morass).

**Lake King area Inflowing waterways: Mitchell, Nicholson and Tambo Rivers and various small creeks**

| Estuarine river reaches | Consumptive water use currently has relatively little impact on freshwater inflows except during the summer/autumn period when low flows can be significantly affected. There is an interim cap on the allocation of surface water from the catchments that flow into Lake King (existing entitlements plus 2,000 ML/yr). There are two existing consumptive water use pressures on the Mitchell River which are both within the existing cap: 1. East Gippsland Water proposes to transfer their existing entitlements from the Nicholson and Tambo Rivers to the Mitchell River (about 2,900 ML/yr). An environmental flow study for the Mitchell River is currently underway to inform the development of suitable extraction rules to be applied to this new volume, based on the values of the freshwater reaches of the river. The estuarine reach and downstream habitats are not included in the study because of they are part of the study area for this scoping study. 2. Existing licence holders are exploring options to increase the reliability of supply under their existing licences via some form of water storage. Their favoured option is a tributary dam and downstream delivery of water via the river. Vegetation re-growth following fire is likely to significantly affect water yield from all catchments. Reductions in inflows due to climate change are likely to be significant. Salt water intrusion will penetrate further into the area due to a combination of reduced inflow and sea level rise. As a result, significant |
| Freshwater wetland | Flow protection: How much can a river’s flow regime be changed before unacceptable ecological changes occur? |
| Variably saline wetlands |  |
| Jones Bay |  | Top-down²
Changes to geomorphic features could occur, in addition to salinity increases. Physical infrastructure is currently used to inhibit the intrusion of salt water up the Mitchell River and into Macleod Morass. There is a need to examine the future role for these types of works in the future.

1. If particular water management options are proposed a top-down 'scenario-based' approach may be needed, instead of, or in addition to, a 'bottom-up' approach.
2. Questions of flow restoration still exist in these systems, so a hybrid method incorporating both approaches may be appropriate.