Goulburn River Environmental Water Management Plan 2015

VICTORIA State Government

GOULBURN BROKEN CATCHMENT MANAGEMENT AUTHORITY

Healthy, resilient and increasingly productive landscapes supporting vibrant communities

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For further information, please contact:

Goulburn Broken Catchment Management Authority
PO Box 1752, Shepparton 3632
Ph (03) 5822 7700 or visit www.gbcma.vic.gov.au

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Abbreviations

CMA	Catchment Management Authorities statutory authorities established to manage regional and catchment, waterways, floodplains, salinity and water quality.
CEWH	Commonwealth Environmental Water Holder (part of the Department of Environment) holds and manages the water entitlements purchased through the Restoring the Balance water recovery program.
GB CMA	Goulburn Broken Catchment Management Authority.
GMW	Goulburn-Murray Rural Water Corporation, trading as Goulburn-Murray Water.
IVT	Inter-Valley Transfers bulk water transfers from the Goulburn supply system to supply water users in the Murray system.
SEWPaC	Department of Sustainability, Environment, Water, Population and Communities responsible for implementing the Australian Government's policies to protect our environment and heritage, and to promote a sustainable way of life.
TLM	The Living Murray an intergovernmental program, which holds an average of 500 000 ML of environmental water per year, for use at six icon sites along the River Murray.
VEFMAP	Victorian Environmental Flow Monitoring and Assessment Program - assesses the effectiveness of environmental flows in delivering ecological outcomes.
VEWH	Victorian Environmental Water Holder an independent statutory body responsible for holding and managing Victorian environmental water entitlements and allocations (Victorian Water Holdings).

Executive Summary

The Goulburn River Environmental Water Management Plan (EWMP) sets out long-term objectives for priority environmental values of the Goulburn River, downstream of Lake Eildon to the Goulburn Weir (mid Goulburn) and from the Goulburn Weir to the Murray River (lower Goulburn). The Environmental Water Management Plan is an important part of the Victorian Environmental Water Planning Framework. It provides the five to ten year management intentions, based on scientific information and stakeholder consultation; that can be used by the respective agencies; Goulburn Broken Catchment Management Authority, Department of Environment, Land, Water and Planning and the Victorian Environmental Water Holder, for both short and long-term environmental water planning.

This Environmental Water Management Plan is not a holistic management plan for the river, but is focused on environmental water management so that the Goulburn River can continue to provide environmental, social and cultural and economic values for all users.

The following components are the main sections featured in this Environmental Water Management Plan.

Hydrology and systems operations

Flow in the Goulburn River downstream of Lake Eildon is regulated by Lake Eildon and the Goulburn Weir. Due to regulation current flows in the mid Goulburn have been significantly altered and high flows now occur in summer to autumn, whilst low flows occur in winter to spring. A natural seasonal flow pattern is partially retained below Goulburn Weir, but is substantially reduced in volume from natural conditions.

Water dependent values

The Goulburn River flows directly into the Murray River and has populations of threatened native fish including Murray cod, Golden perch, Freshwater catfish and Australian smelt. The river provides important in-stream habitat for aquatic fauna and has areas of River Red Gum canopies along the river banks. Many native vegetation communities within the catchment are considered endangered or vulnerable.

Ecological condition and threats

The Goulburn River is currently in 'Very Poor Health' in accordance to the Sustainable Rivers Audit (SRA 1 and SRA 2). The Index of stream condition scores of 2010 however describe reaches along the river from Moderate to Excellent depending on the reach. Instream vegetation on the mid Goulburn has seen an increase in macrophytic growth. In the lower Goulburn amphibious vegetation has begun to re-establish during 2013-2014 on the lower banks following the loss of vegetation during the extended drought and then floods. Overall condition of the native fish populations in the mid Goulburn has been classed as moderate (reach 3) to poor (reaches 1 and 2), with major threats being low water temperatures and competition from non-native species.

Bank notching was also an issue that occurred in the lower reaches in 2012-2013 and again in 2013-2014. Notching occurred after environmental water deliveries in these years, but the exact reason for the notching remains unclear.

Management objectives

The long term management goal that has been defined for the Goulburn River is 'To provide flow regimes that protect and improve the Goulburn River's important aquatic flora and fauna, instream habitats, connected floodplains and ecological processes'.

The ecological and hydrological objectives that sit under the long-term management goal have been determined by various flow studies and technical reports and prescribe the environmental watering regime for the river.

Managing risks to achieving objectives

Threats to achieving ecological objectives include low dissolved oxygen (DO), invasive species (carp breeding or invasive non-native flora) and cold water releases from Lake Eildon. External threats to environmental water could be instream barriers to fish movement and grazing of riparian vegetation.

Environmental water delivery infrastructure

The constraints to the delivery of environmental water such as bankfull flows have been identified as the lack of capacity to release large volumes of water from Lake Eildon without the effects of potential flooding, bed and bank erosion and possible infrastructure damage. Potential cold water pollution effects on expected ecological outcomes, lack of flexibility in operations due to level of commitment, high demands for Goulburn River water outside the catchment and balancing the differences in volumes required to inundate floodplain areas.

Demonstrating outcomes

Monitoring is required to allow the Goulburn Broken CMA to adaptively manage annual environmental watering. It is also required to enable the Goulburn Broken CMA, Commonwealth Environmental Water Holder and the Victorian Environmental Water Holder to demonstrate the long-term outcomes of the implementation of the Goulburn River Environmental Water Management Plan. As the state is currently reviewing the Victorian Environmental Flows Monitoring and Assessment Program, the Goulburn River Environmental Water Management Plan recommends monitoring activities that will meet monitoring requirements.

Knowledge gaps

The management actions in the Goulburn River Environmental Water Management Plan are based on the best available information. A number of knowledge gaps have been identified during the development of the Environmental Water Management Plan, particularly around lack of macroinvertebrates and biomass, cold water pollution and its effects on native fish, baseflows, freshes producing the extent of scouring they are aimed at and the recommended rates of rise and fall from reservoirs.

Acknowledgements

The Goulburn Broken Catchment Management Authority acknowledges the Traditional Owners of the land in the Goulburn Broken Catchment. The Catchment Management Authority strongly respects the rich culture and intrinsic connection the Traditional Owners have to the land and the contribution and interest of Aboriginal people and organisations in land and natural resource management.

The information contained in the Goulburn River Environmental Water Management Plan has been sourced from a variety of reports and individual knowledge and expertise. The Goulburn Broken CMA acknowledges the assistance of the following people for contributing to this EWMP.

- Suzanne Witteveen and Susan Watson – Department of Environment, Land, Water and Planning
- Sam McGrath – Goulburn-Murray Water
- Terry Hillman and Jane Roberts – Expert Review Panel
- Simon Casanelia, Geoff Earl, Meegan Judd, Peta Richie and Mark Turner – Goulburn Broken CMA

1. Introduction

Environmental water management in Victoria is entering a new phase as ongoing water recovery sees significant volumes of water being returned to the environment. The increasing environmental water availability is providing new opportunities to protect, restore and reinstate high value ecosystems throughout northern Victoria. The spatial coverage of environmental water has expanded considerably in recent years and this trend will continue into the future.

Environmental watering in Victoria has historically been supported by management plans, which document key information such as the watering requirements of a site, predicted ecological responses and water delivery arrangements. State and Commonwealth environmental watering programs now have the potential to extend beyond those sites that have been watered in the past. Therefore, new environmental water management plans are required to provide a transparent and informed approach to environmental water delivery across new environmental watering sites (Figure 1).

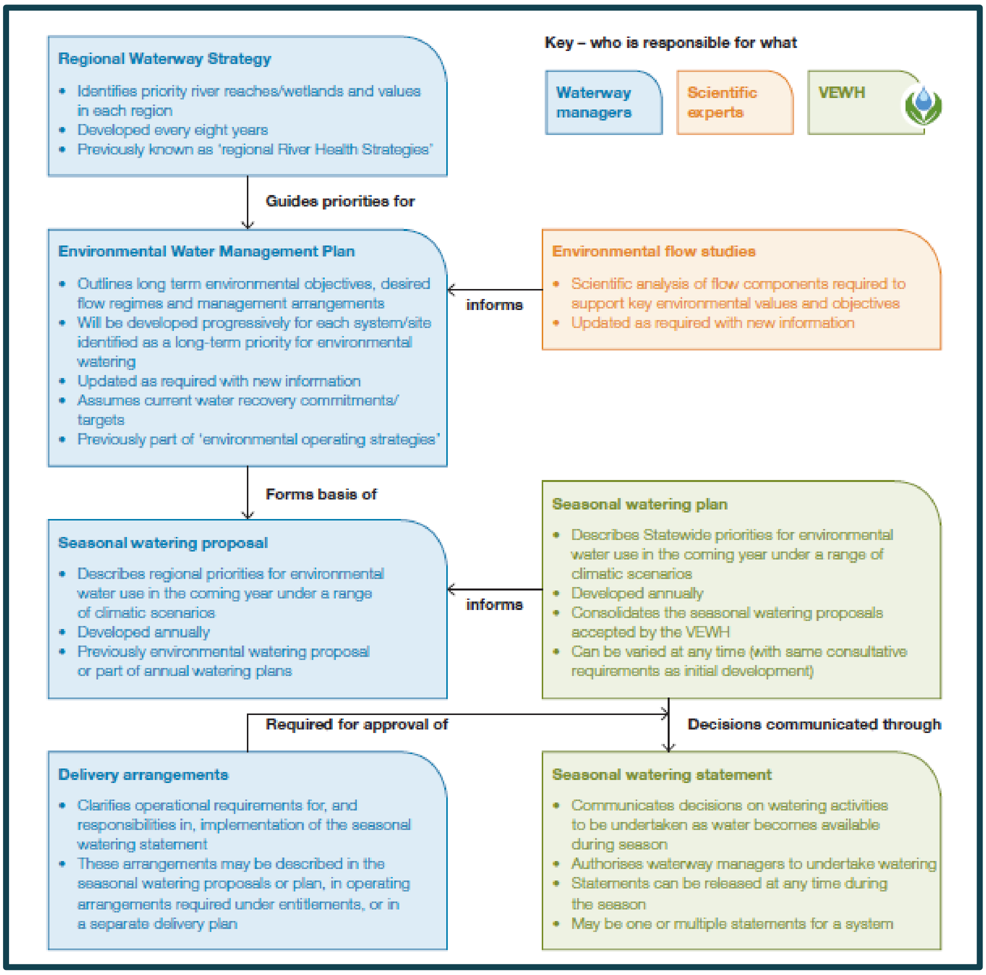


Figure 1: Planning framework for decisions about environmental water management in Victoria.

The Goulburn Broken Catchment Management Authority was funded by the Department of Environment, Land, Water and Planning – *Victorian Basin Plan Environmental Water Management Plan Program* to prepare an Environmental Water Management Plan for the Goulburn River. The Environmental Water Management Plan will inform the development of seasonal watering proposals for the Goulburn River.

1.1 Purpose and Scope

This Environmental Water Management Plan (EWMP) has been prepared by the Goulburn Broken Catchment Management Authority (GB CMA) to establish the long-term management goals of the Goulburn River (reaches 1-5). This document is a ten year management plan that describes the ecological and hydrological objectives of the Goulburn River and is based on both scientific information and stakeholder consultation and will be used by the Goulburn Broken Catchment Management Authority to inform annual watering decisions.

The purpose of the Goulburn River EWMP is to:

- Identify the long-term objectives and water requirements for the river, identified as a high priority by the Goulburn Broken CMA.
- Provide a vehicle for community consultation, including for the long-term objectives and water requirements of the river.
- Inform the development of seasonal watering proposals and seasonal watering plans.
- Inform Long-term Watering Plans that will be developed by the State under the '*Basin Plan - Chapter 8*' (DEPI, 2014).

This watering plan is not a holistic plan for the site as it is limited to issues related to the management of water dependent values and environmental water.

1.2 Development Process

Information used in the development of this plan was compiled from various sources including:

- Mid Goulburn River FLOWS study (Cottingham et al., 2014b).
- Mid Goulburn River Environmental Flows study: Issues Paper (Cottingham et al., 2014a).
- Goulburn River Seasonal Watering Proposal (GBCMA, 2014c).
- Goulburn Broken Waterway Strategy 2014-2022 (GBCMA, 2014b).
- Goulburn River Seasonal Watering Proposal 2015-2016 (GBCMA, 2015).
- Flow related environmental issues associated with the Goulburn River below Lake Eildon (Cottingham et al., 2003).
- Evaluation of summer inter-valley transfers from the Goulburn River (Cottingham et al., 2007).

This information was supplemented by discussions with people with an intimate knowledge of the river, its environmental values and the management and operation of the system.

2. Catchment Setting

The Goulburn River is 570 km long and flows from the Great Dividing Range upstream of Woods Point to the Murray River east of Echuca. The river flows through major towns such as Seymour, Nagambie and Shepparton. It has a mean annual discharge of approximately 3040 GL representing 13.7 per cent of the total state discharge (Cottingham et al., 2013). The Goulburn River has the characteristics of a relatively steep foothills stream immediately below Lake Eildon. The river then takes on the characteristics of a lowland river with a relatively lower gradient and more extensive floodplain downstream of Seymour (Cottingham et al., 2014b). The Goulburn River Basin is Victoria's largest covering 1.6 million hectares or 7.1 per cent of Victoria and was identified as a high priority waterway in the Goulburn Broken Waterway Strategy due to its significant environmental values (GBCMA, 2014b).

The catchment contains diverse landscapes, communities and natural and constructed features. The landscape ranges from snow-covered alps, forests, granitic outcrops, sloping plains, box woodlands and red gum floodplains and a mosaic of natural assets, river pathways, forested regions and agricultural development (GBCMA, 2014b). The catchment is home to over 204 000 people, which includes 6000 indigenous Australians, many who identify as Traditional Owners of the area (GBCMA, 2014a). Changes in catchment land use since European settlement and the operation of Eildon Dam since 1955 has affected the flow and sediment regime of the mid Goulburn River. The channel and floodplain have since undergone a number of physical changes over time, which have impacted on the quality of the physical habitat and the ecological health of the river system.

Average annual rainfall varies substantially within the catchment, from 1600 mm in the south-east slopes to 400 mm in the north-west, occurring mainly in winter and spring. Rainfall can vary considerably from year to year with long periods over several years or decades that are considerably wetter or drier than others (Earl, 2011b). The average annual surface water availability for the Goulburn Broken Region is 3233 GL/year. Current average surface water diversions (including water supplied and channel and pipe losses) within the Goulburn Broken region are 1099 GL/year. A further 507 GL/year is transferred to the Campaspe, Loddon-Avoca and Wimmera regions via the Waranga Western Main Channel (Earl, 2011b).

Summer in the Goulburn Broken region ranges from warm in the elevated southern region (average daily temperatures less than 25°C) to hot in the northern areas (more than 30°C). Winters are milder on the plains but cold in the mountainous areas in the south (DSE, 2013). The average rainfall runoff between 1997 and 2006 was 15 and 41 per cent lower respectively than the long term (1895 to 2006 average) values. If this climate was to continue, average surface water availability would be reduced by 58 per cent and the volume of water diverted for use within the region would be reduced by 25 per cent (Earl, 2011b).

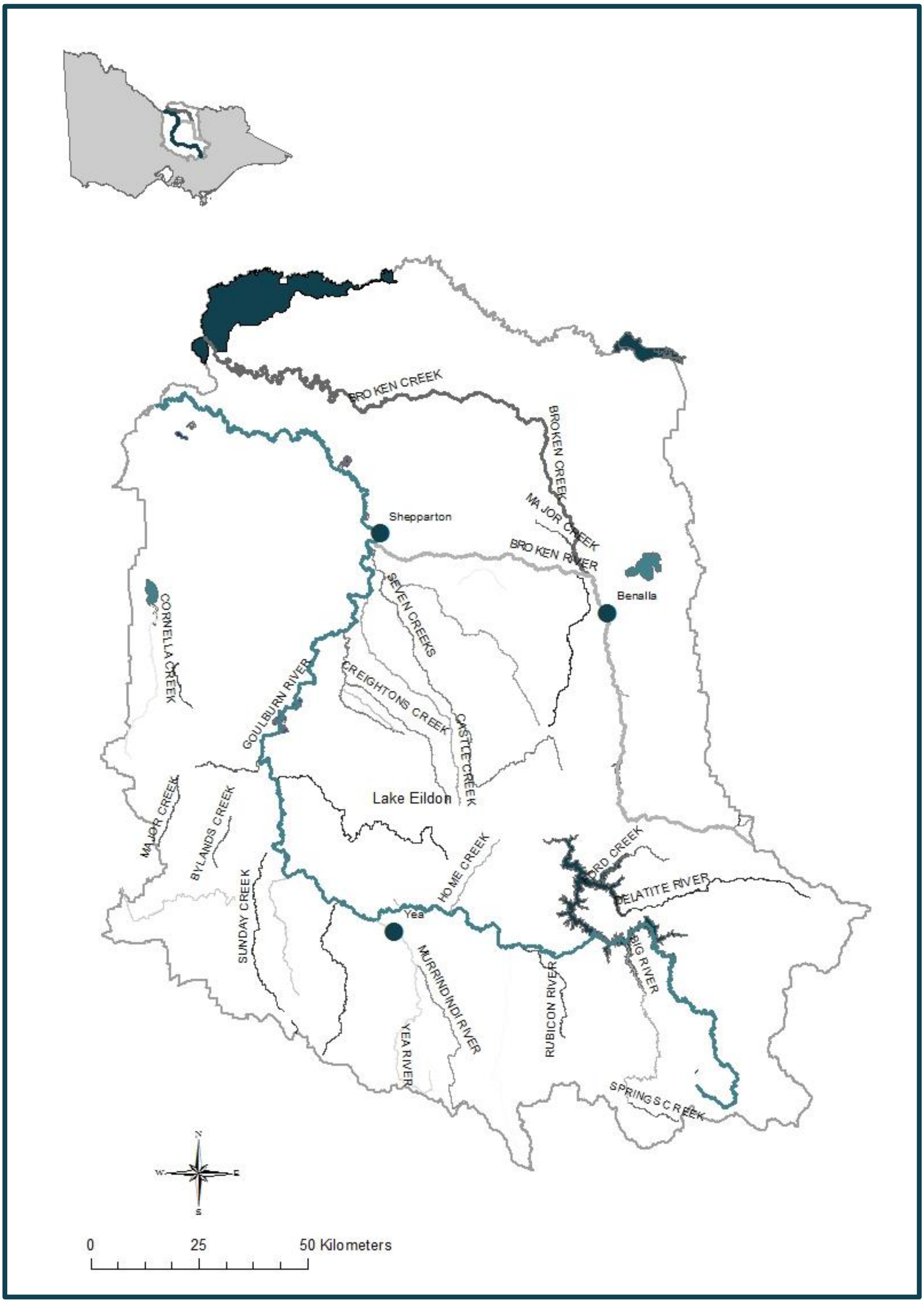


Figure 2: Goulburn River in the Goulburn Broken Catchment

2.1 Hydrophysical characteristics

The Goulburn River is divided into three sections by water supply infrastructure:

1. Upstream of Lake Eildon (Upper Goulburn)
2. Lake Eildon to the Goulburn Weir (Mid Goulburn), and
3. Goulburn Weir to the River Murray (Lower Goulburn).

The Upper Goulburn is unregulated and outside the scope of this Environmental Water Management Plan.

For environmental water management purposes the mid and lower Goulburn River is divided into five representative reaches, starting at Lake Eildon and terminating at the Murray River near Echuca (Figure 2). The two major water regulation structures on the river are Lake Eildon and Goulburn Weir. The mid-section and part of the lower section of the Goulburn River between Lake Eildon and Shepparton have a confined floodplain up to four kilometres wide. Constructed levees confine the wide floodplain along the lower Goulburn River below Shepparton (GBCMA, 2007).

The mid Goulburn River (reaches 1-3) and the lower Goulburn River (reaches 4-5) are separated by the Goulburn Weir. This barrier results in highly regulated flows managed at different scales, depending on the objective of the planned event. Releases into the mid Goulburn River are from Lake Eildon and releases into the lower Goulburn River are from Goulburn Weir. Watering events in the mid Goulburn can be independent of a watering event in the lower Goulburn, but watering events in the lower Goulburn impact on the mid Goulburn River.

There are many tributaries of the Goulburn River which provide natural flows into the system. These include the Rubicon, Acheron and Yea Rivers and King Parrot and Hughes Creeks in the mid Goulburn River and the Broken River and Sevens Creeks in the Lower Goulburn. The regulation of the River for irrigation purposes means water is stored along the River, with diversions into GMW irrigation network at Goulburn Weir, Inter-Valley Transfers (IVTs) through to the Murray River or via the Waranga Main channel to the Campaspe and Loddon, and landholders extracting water along the river.

The floodplain width generally ranges from 500 metres to two kilometres and is made up of wetlands and paleo channels that are hydrologically connected to the channel at various flows. Reach one and two has hundreds of small floodplain wetlands, many being five hectares or less. This is impart caused by artificially constructed block banks and culverts limiting their size. A small number of these wetlands have had their condition assessed and are considered to be in moderate to good condition. However, they suffer from altered water regimes due to irrigation and water supply in the wrong time of year plus lack of overbank flows.

The Goulburn River downstream of Lake Eildon is classified as a Heritage River under the *Heritage Rivers Act* 1992 (Vic).

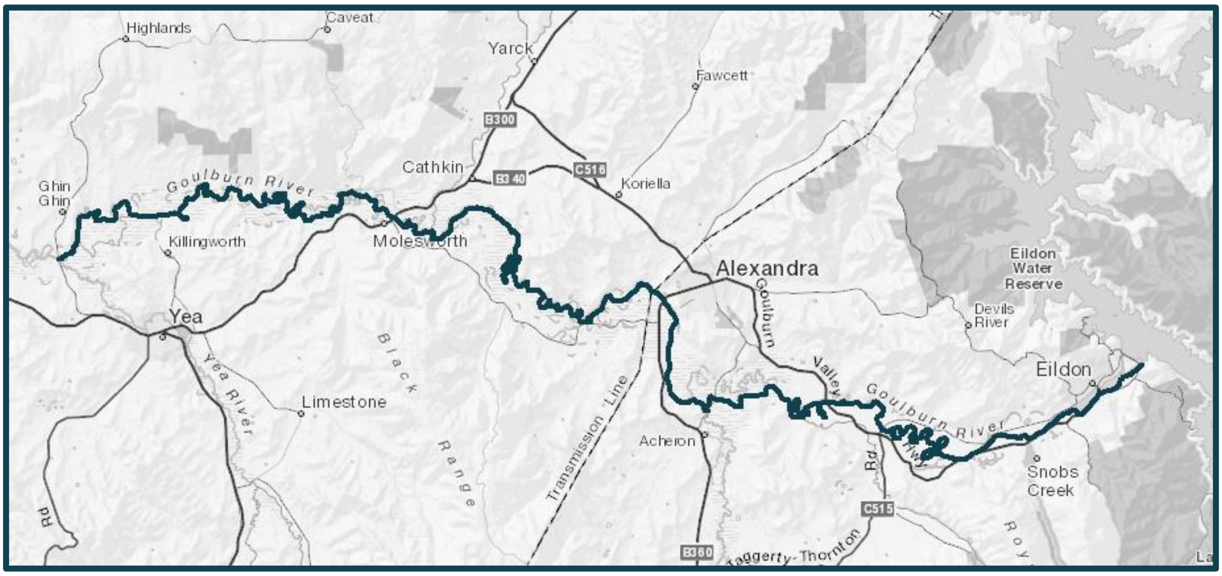
2.1.1 Mid Goulburn River

The mid Goulburn is regulated by Lake Eildon and Goulburn Weir where flows are greatly reduced in winter/spring by the capture of run-off and river flows into Lake Eildon. Flows during autumn and summer are greatly increased due to irrigation and consumptive release to meet downstream demand. As a result, there are limited opportunities during this time to manage water for environmental purposes in reaches 1-3 (Cottingham et al., 2013).

Lake Eildon has a capacity of 3 334 000 ML, which is approximately twice the average annual flow in the Goulburn River. Lake Eildon functions with such a large capacity, operation of the lake fully regulates downstream flows in all but wet years. The mid Goulburn is divided into three reaches:

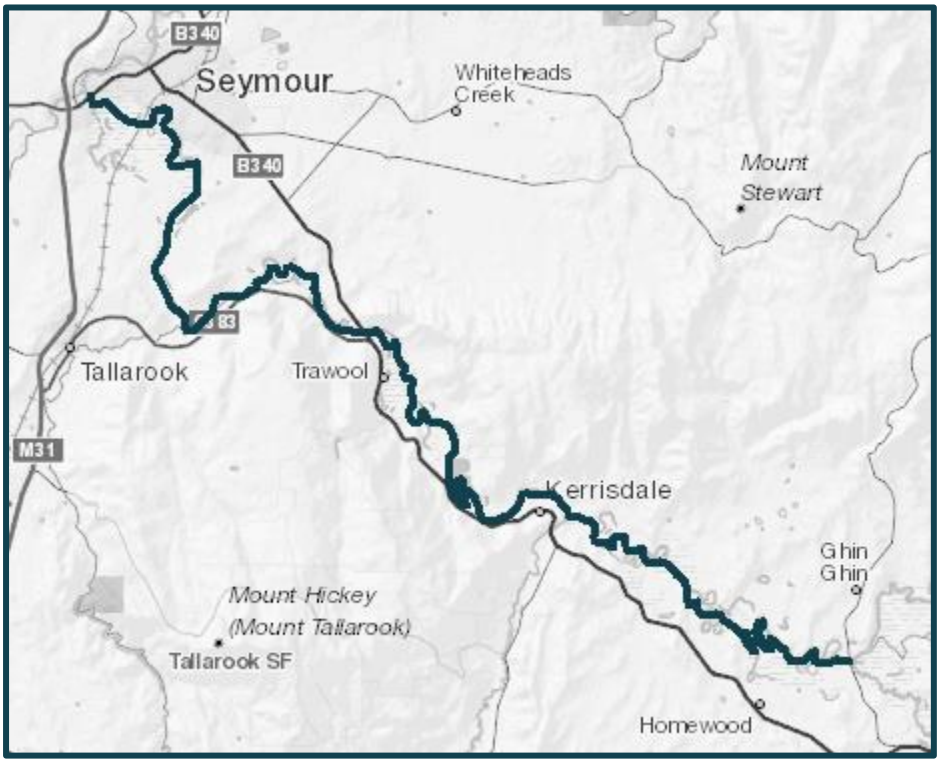
- Reach 1: Downstream of Lake Eildon to Yea, extending 85 km.
- Reach 2: Yea River confluence to Sunday Creek, extending 45 km.
- Reach 3: Sunday Creek to Nagambie (upstream of Goulburn Weir), extending 65 km.

Reach 1 – The principle features of this reach are:



- A relatively straight channel between Lake Eildon to Alexandra, and a sinuous with point bars between.
- Riffles and runs with pools (often extending for hundreds of metres).
- Many wetlands and billabongs with varied commence-to-flow levels.
- Gravel/cobble armoured bed (overlaying sand).
- Vegetated gravel and cobble bars common (some terrestrialisation).
- Vegetated benches.
- Reasonable levels of large wood, mainly in lower section.

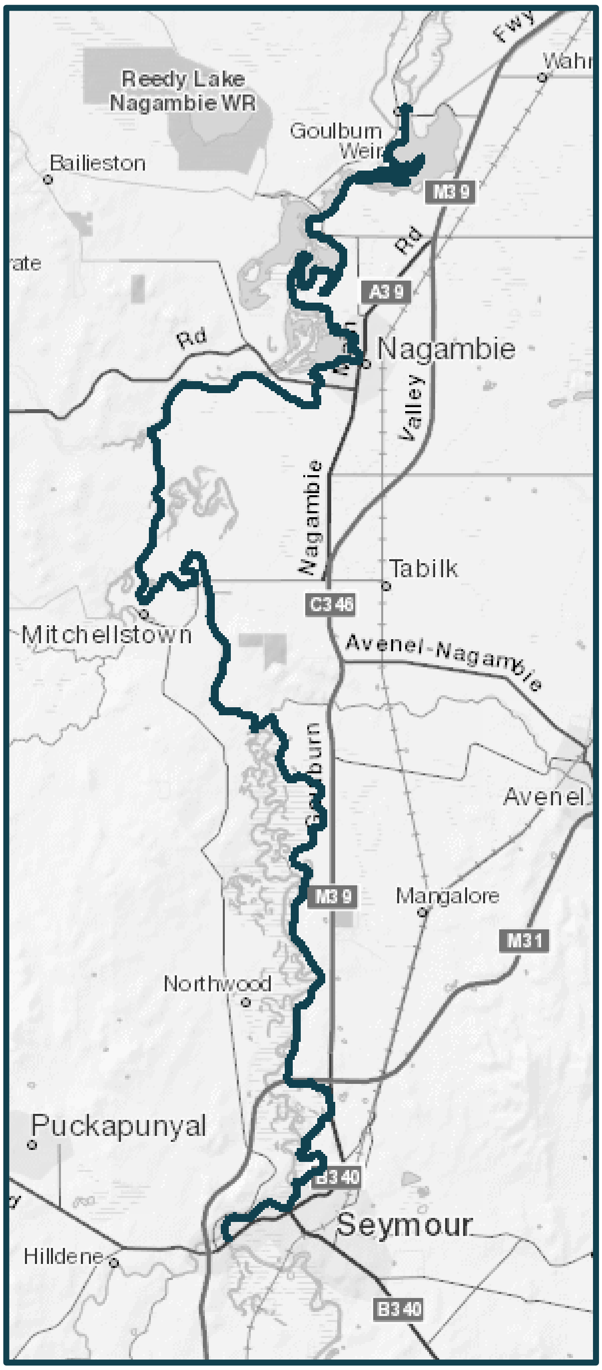
Reach 2 – The principle features of this reach are:



- Medium sinuosity occasionally confined by the valley margins.
- The highest wetland number per kilometre (~13 km) and the highest wetland area, with some extensive wetlands (e.g. Horseshoe Lagoon).
- Gravel/cobble armoured bars evident (some sand underneath), with fine-grained sediments (silts and clays with coarser substrates).
- Occasional bedrock controls (with boulders) creating cascades and extensive pools, particularly when confined on both margins (e.g. Trawool).
- Diverse sediments due to geology of sedimentary and granitic materials.
- Extensive benches.
- Riffles and runs with pools, often extending for hundreds of metres.
- Vegetated gravel and cobble bars common (some terrestrialisation).

Reach 3 – The principle features of this reach are:

- A lower gradient channel with alternating planform from straight to medium sinuosity.
- Extensive floodplains, some valley confinement.
- Dredging of sediment (near Seymour between 1960 and 1980) has impacted sediment transport throughout the reach and is likely to continue to reduce downstream sediment transport.
- Some wetlands but the least of the three mid Goulburn reaches by number and area.
- Deeper, wider channel well engaged with floodplain.
- Some historic bank erosion evident likely to be associated with low riparian vegetation density.
- Extensive benches in lower sections.
- Bed substrates are finer-grained gravels, sands and silts.
- High levels of large wood.



2.1.2 Lower Goulburn River

Flows in the lower Goulburn River are reduced throughout the year, but still retain some seasonal pattern. Most tributaries in this reach are ephemeral and add natural flow patterns to the river. The Broken River is the main tributary in terms of inflows and joins the Goulburn River at Shepparton. In recent years significant flows have been released in summer and early autumn from the Goulburn Weir to the Murray River as Inter-Valley Transfers to supply entitlements traded from the Goulburn to the Murray system.

Along the lower Goulburn River the channel is perched and its floodplain is characterised by natural and constructed levees. The lower Goulburn River from Goulburn Weir to the River Murray is listed in '*A Directory of Important Wetlands'* (EA, 2001). The floodplain consists of a large area of habitat for fauna such as waterbirds and fish. It has a wide variety of wetland types and vegetation types, and is an excellent example of a major floodplain system (GBCMA, 2007). Organic matter is provided from floodplain sources to the river channel.

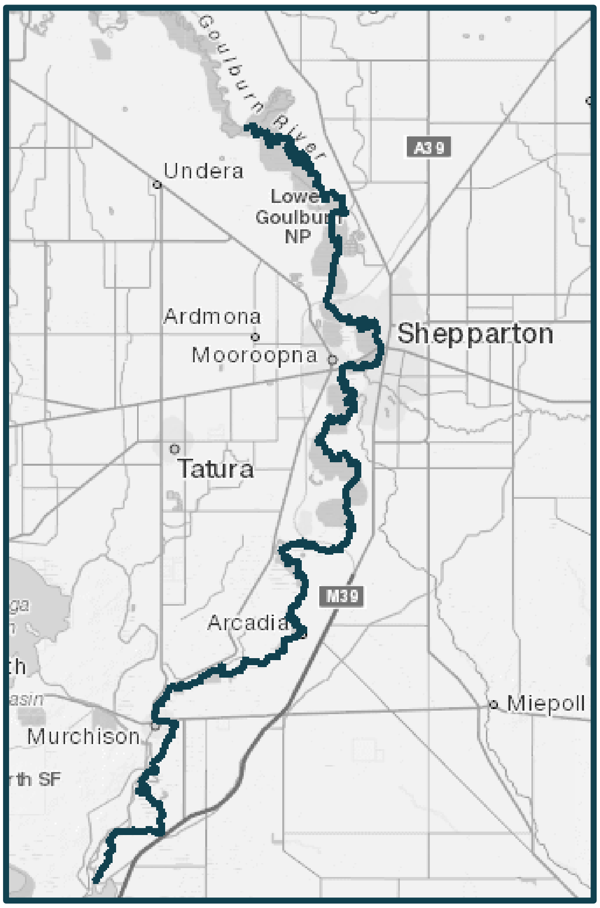
For management purposes the lower Goulburn is divided into two reaches:

- Reach 4: Nagambie (downstream of Goulburn Weir) to Loch Garry, extending 110 km.
- Reach 5: Loch Garry to the Murray River, extending for 125 km.

During winter and spring, environmental flows delivered to reaches four and five can also benefit reaches 1-3 in the mid Goulburn.

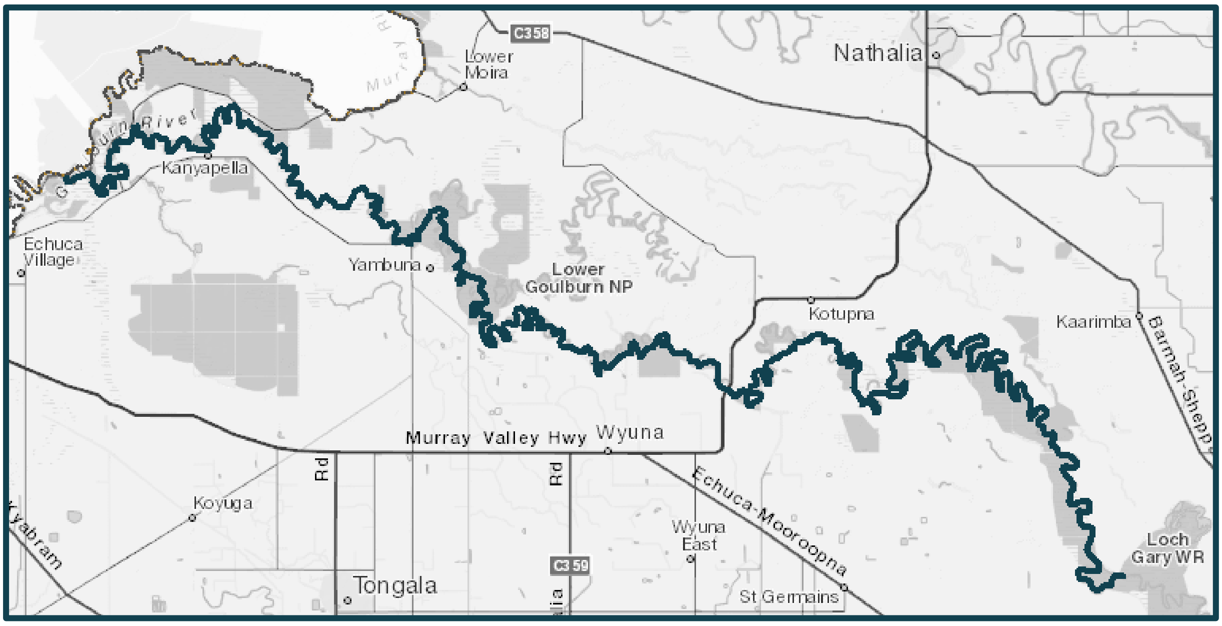
Reach 4 – The principle features of this reach are:

- A low gradient river flowing through the alluvial sediments of the Shepparton Formation (rather than bedrock).
- Incised river cutting into sand and clay with bedload characterised by mud and clay.
- Varied floodplain width (but generally wider than reaches 1 – 3).
- A number of benches and point bars.
- A reasonable level of instream large woody debris.



Reach 5 – The principle features of this reach are:

- A narrower floodplain than upstream (Cottingham et al., 2003). Loch Garry is a natural depression downstream of Shepparton (16 km) and carries floodwater, released through the Loch Garry regulator when flows reach a certain height on the Shepparton gauge.
- Two year flood events generally contained within levees downstream of Shepparton.
- Capacity of the river channel to contain floods is lowest in this reach of the river.
- In the lower sections of this reach there are a number of distributary channels (e.g. Deep Creek and Wakiti Creek) that flow into the Murray River upstream of Barmah sand hills.
- Increased low flows due to regulation have resulted in the river cutting a narrower channel characterised by steep, actively eroding toes of the bank (Cottingham et al., 2003) .
- Significant reach for native fish habitat and spawning.
- Largely reduced and narrow riparian/floodplain vegetation.



2.2 Land Status and Management

2.2.1 Land status

The Goulburn River flows through a mixture of private, public and Crown land riparian frontages. Many large private property holdings have historical property titles which give ownership to the middle of the river.

Parks Victoria manage large sections of land on and surrounding the river, especially in the lower reaches. Land that was previously managed privately through grazing licenses have gradually been changed to management by Parks Victoria on much of the river. Parks Victoria also manages the Lower Goulburn National Park, the Shepparton Regional Park and various smaller reserves along the length of the river including many lagoons and wetlands.

2.2.2 Environmental Water Management – Roles and Responsibilities

Management of environmental water involves a number of agencies including the Victorian and Commonwealth Environmental Water Holders, the Murray-Darling Basin Authority and Goulburn-Murray Water. Table 1 provides an outline of the agencies and groups involved in environmental water management in the Goulburn River downstream of Lake Eildon.

Deliveries of environmental water are managed by Goulburn-Murray Water. Releases to the mid Goulburn River are made from Lake Eildon and take into consideration inflows from tributaries between Lake Eildon and Goulburn Weir. Water delivery in these reaches can be independent of an event delivered in the lower Goulburn River.

Goulburn-Murray Water manages land around the pondage below Lake Eildon and land to the high water mark surrounding Goulburn Weir. Goulburn-Murray Water is primarily responsible for water delivery for irrigation purposes along the river. Goulburn-Murray Water owns and maintains assets such as Lake Eildon and Goulburn Weir.

Management of the River is undertaken primarily by the Goulburn Broken CMA. The Goulburn Broken CMA is responsible for structural and engineering works along the river, in order to improve water quality and river condition. Permits must be obtained through the Goulburn Broken CMA before any works are undertaken that impact upon the river.

Releases to the lower Goulburn River are from the Goulburn Weir, involving Lake Eildon releases and/or inflows from tributaries downstream of the lake. Events in the lower Goulburn will usually impact on the mid Goulburn River due to releases from Lake Eildon. Goulburn Weir flows can be diverted to Waranga Basin (storage capacity 432 GL) to manage environmental water deliveries if large unexpected run off occurs after water is released from Lake Eildon.

Table 1: Parties involved in Environmental Water Management

PARTY	INVOLVEMENT
Department of Environment, Land, Water and Planning **(DELWP)**	Manage the water allocation and entitlements framework. Develop state policy on water resource management and waterway management approved by the Minister for Water and Minister for Environment and Climate change. Develop state policy for the management of environmental water in regulated and unregulated systems. Act on behalf of the Minister for Environment and Climate change to maintain oversight of the Victorian Environmental Water Holder and waterway managers in their roles as environmental water managers.
Commonwealth Environmental Water Holder (CEWH)	Make decisions about the use of Commonwealth water Holdings, including providing water to the Victorian Environmental Water Holder for use in Victoria. Liaise with the Victorian Environmental Water Holder to ensure co-ordinated use of environmental water in Victoria. Report on management of Commonwealth water holdings.
Goulburn Broken Catchment Management Authority **(GB CMA)**	Identify regional priorities for environmental water management in the regional waterway strategy. Assess water regime requirements of priority rivers and wetlands to identify environmental watering needs to meet agreed objectives. Identify opportunities for and implement, environmental works to use environmental water more efficiently. Propose annual environmental watering actions to the Victorian Environmental Water Holder and implement its environmental watering decisions. Provide critical input to management of other environmental water (e.g. passing flows management) and report on environmental water management activities undertaken.
Goulburn-Murray Water (GMW)	Water Corporation – Storage Manager and Resource Manager Work with the Victorian Environmental Water Holder and waterway managers in planning for the delivery of environmental water to maximise environmental outcomes. Operate water supply infrastructure such as dams and irrigation distribution systems to deliver environmental water. Ensure the provision of passing flows and compliance with management diversion limits in unregulated and groundwater systems.
Goulburn River Environmental Water Advisory Group (Goulburn EWAG)	Consists of stakeholders and community representatives who provide advice to the GB CMA on the best use of environmental water for the Goulburn River.
Local councils **Council of Greater Shepparton** **Moira Shire**	Informed of future flow events for potential impacts on their activities. Moira Shire are part land managers of Kinnairds Wetland at Numurkah and assist with decision making around environmental water delivery to this wetland.
Murray-Darling Basin Authority (MDBA)	Implementation of the Murray-Darling Basin Plan. The plan sets legal limits on the amount of surface water and groundwater that can be taken from the Basin from July 1 2019 onwards. Integration of Basin wide resource management and manager of The Living Murray water entitlements.
Parks Victoria (PV)	Land Managers. Implement relevant components of Environmental Water Management Plans. Operate, maintain and replace (as agreed), the infrastructure required for delivery of environmental water, where infrastructure is not part of the GMW irrigation system
Traditional Owners **Yorta Yorta and Taungarung**	Inform Indigenous Groups on the proposal and seek advice on indigenous related issues.
Victorian Environmental Water Holder (VEWH)	Make decisions about the most effective use of Water Holdings, including use, trade and carryover. Authorise waterway managers to implement watering decisions. Liaise with other water holders to ensure coordinated use of all sources of environmental water. Communicate all environmental watering decisions and outcomes.

Other groups with an interest in environmental watering include environmental groups, recreational users, other environmental water entitlement holders, landholders and local communities. It is important that the interests and values of these groups are incorporated in planning for and management of environmental water (DEPI, 2014).

2.3 Environmental water sources

The Goulburn River has a number of environmental water sources which are described below and summarised in Table 2.

Water shares are classed by their reliability in Victoria and are all legally recognised. High reliability water shares (HRWS), secure entitlement to a defined share of water. Low reliability water shares (LRWS) have a relatively low reliability of supply (except on the Broken and Ovens Rivers). Allocations are made to high reliability water shares before low reliability shares (Earl, 2011a). In the Goulburn system, a 100 per cent HRWS allocation occurs in 97 per cent of years and the minimum HRWS is 73 per cent of years. A 100 per cent LRWS allocation occurs in 42 per cent of years and a zero LRWS in 24 per cent of years (Earl, 2011b).

Water available in the Goulburn River includes:

- Minimum passing flows and a water quality allowance established in the Bulk Entitlement (Eildon – Goulburn Weir) Conversion Order 1995 and subsequent amendments.
- Environmental entitlements held by the Victorian Environmental Water Holder, the Commonwealth Environmental Water Holder and the Murray-Darling Basin Authority.
- Unregulated flows (not listed).

Bulk Entitlement (Eildon – Goulburn Weir) Conversion Order 1995

The right to water in the Goulburn River was defined through the Bulk Entitlement (Eildon-Goulburn Weir) Conversion Order 1995. This includes provision of 'passing flows' within Goulburn-Murray Waters Bulk Entitlement, as well as protecting unregulated river flows. Passing flows are specified at Eildon, Goulburn Weir and McCoys Bridge. As a drought response measure, a later amendment (2012) allows for the reduction and banking of passing flows at Lake Eildon for later deployment.

Environmental Entitlement (Goulburn System – NVIRP Stage 1) 2012

Held by the Victorian Environmental Water Holder, this entitlement holds one third of the water recovered from the channel modernisation program, up to a long-term average of 75 000 ML, plus mitigation water. While the modernisation program is being implemented, water is made available annually based on losses saved in the preceding year.

Goulburn River Entitlement 2010

Held by the Victorian Environmental Water Holder (VEWH), this entitlement is made up of 8851 ML of HRWS (made up of 7417 ML in Zone 1A -Goulburn, 1434 ML in Zone B-Boort) and 3140 ML of LRWS (in Zone 1A – Goulburn) (refer to Figure 3).

Goulburn Water Quality Reserve

The reserve sets aside 30 GL of water that can be released to meet any water quality problems in the river, subject to competing needs from the lower Broken Creek. This is available in any year.

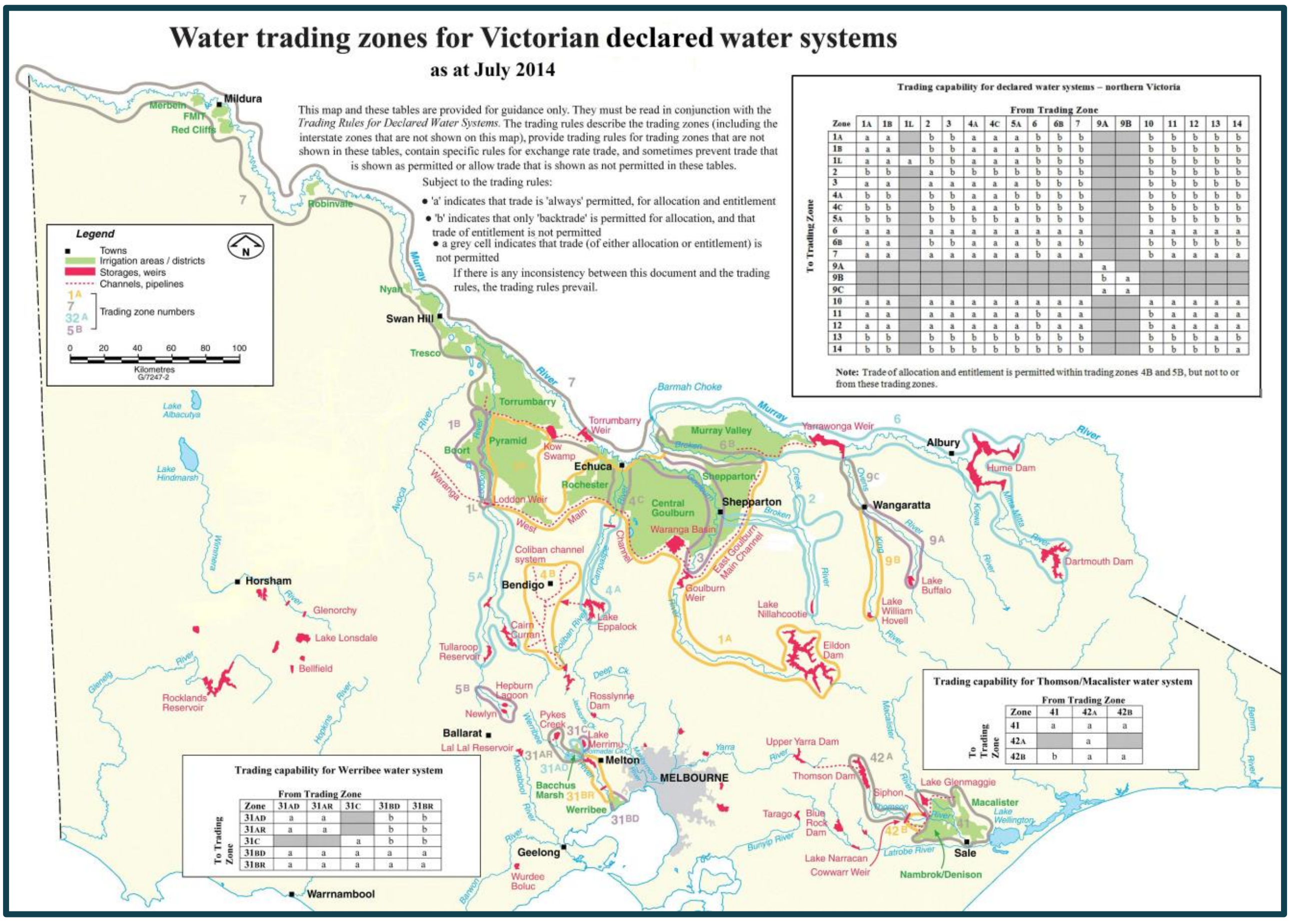


Figure 3: Water trading zones for Victoria
Taken from Vic Water Register

Commonwealth Environmental Water Holder (CEWH)

Under the Federal Government's water buyback scheme or '*Restoring the Balance in the Murray-Darling Basin*' program as at 11th March 2015, a total of 246 002 ML of HRWS and 22 400 ML of LRWS has been acquired in the Goulburn River system. This water is held by the CEWH, which is primarily responsible for its management and deployment. The stated objective of this program is to purchase water entitlements so that the water can be used for environmental purposes (RWC, 1987). The water purchased from the Goulburn River catchment can be used to benefit environmental assets in this catchment and downstream. The CEWH also has the option to trade water in and out of the Goulburn as required. The use of water in the Goulburn River system is not guaranteed and is at the discretion of the CEWH.

Environmental Entitlement (Goulburn System – The Living Murray) 2007

This entitlement is managed by the Murray-Darling Basin Authority (MDBA) and holds 39 625 ML HRWS and 156 980 ML LRWS in the Goulburn Water supply system. This water is to be used for the Living Murray icon sites. However, this water can provide environmental benefits in the Goulburn River en route to the Murray River. The use of this water in the Goulburn system is not guaranteed and is at the discretion of the MDBA.

Bulk Entitlement (River Murray Flora and Fauna) Conversion Order 1999

The Victorian River Murray Flora and Fauna Bulk Entitlement provides 27 600 ML of HRWS in the Murray system. It is held by the VEWH for the purpose of providing for flora and fauna needs. It has been used in a range of wetlands including the Barmah Forest (Icon site) and the Goulburn River system wetlands. It can also be traded on the water market on an annual basis. The use of this water in the Goulburn River system is not guaranteed and is at the discretion of the VEWH.

Inter-Valley Transfer – Goulburn Valley Account

The Goulburn Inter-Valley Transfer (IVT) provides water from the Goulburn River System (Lake Eildon) allocated to downstream diverters. This is normally delivered via the Lower Goulburn River to the Murray River and can provide minimum environmental flow needs during some of the summer and autumn. Inter-Valley Transfers can also contribute to spring and summer/autumn freshes (GBCMA, 2008). This reduces the need to deploy water from environmental entitlements.

Table 2: Summary of environmental water sources available and responsible agencies for the Goulburn River System

ENVIRONMENTAL WATER	RESPONSIBLE AGENCY	DESCRIPTION	CONDITIONS
Bulk Entitlement (Eildon – Goulburn Weir) Conversion Order 1995			
Minimum flow	GMW	Minimum flow of 120 ML/day at Eildon Pondage Weir.	[1]
Minimum flow	GMW	Minimum average weekly flow of 250 ML/day at the Goulburn Weir.	The daily rate is to be no less than 200 ML/day.[1]
Minimum flow	GMW	Minimum average monthly flow of 350 ML/day from November to June (inclusive) at McCoys Bridge gauging station.	The daily rate is to be no less than 300 ML/day.[1]
Minimum flow	GMW	Minimum average monthly flow of 400 ML/day from July to October (inclusive) at McCoys Bridge gauging station.	The daily rate is to be no less than 350 ML/day.[1]
Goulburn Water Quality Allowance	GMW	30 GL per year.	Maintenance of water quality.
Additional Passing Flow below Eildon Pondage Weir	GMW	Minimum passing flows at Eildon Pondage Weir increased to 250 ML/day.	Inflows to Lake Eildon for previous 24 months must reach a specified volume.[1,2,3]
Additional Passing Flow below Eildon Pondage Weir	VEWH	Up to 80 GL in November to provide up to 16 000 ML/day peak flow for 1 day.	Inflows to Lake Eildon from previous 12 and 24 months must reach specified volumes and VEWH confirms the need for a release.[1]
Environmental Water Entitlements			
Goulburn Environmental Water Savings Supply Deed	VEWH	One third of water savings created in the Goulburn System as a result of modernisation works completed as part of Stage 1 of the Northern Victorian Irrigation Renewal Project. 30 GL is assumed to be available for 2015-2016.	Volume based on works implemented and water losses saved in previous year's climate.
Goulburn River Entitlement 2010	VEWH	8851 ML of high reliability water savings (made up of 7417 ML in zone 1A – Goulburn; 1434 ML in Zone B – Boort) and 3140 ML of low reliability water share (in Zone 1A – Goulburn).	The purpose of this entitlement is to grant the VEWH and environmental entitlement for water.
Environmental Entitlement (Goulburn-System – Living Murray) 2007	MDBA	39 625 ML high reliability entitlement and 156 980 ML low reliability entitlement.	Water allocated to this entitlement must be used for the Living Murray 'icon sites'. However, this water can provide environmental benefits in the Goulburn River en route to the Murray River.
Commonwealth Environmental Water Holdings	CEWH	246 002 ML Goulburn high reliability water share and 22 400 ML Goulburn low reliability water share as at 11 March 2015.	Water use is subject to agreement with the CEWH.

1 Minimum flows in the Goulburn Bulk Entitlement can be reduced under drought conditions and banked for later use.

2 The minimum flow downstream of Lake Eildon is increased to 250 ML/day in any month when the volume of inflow to Lake Eildon during the previous 24 months exceeds the volume specified in Table 1 of Schedule 6 of the Bulk Entitlement.

3 24 month trigger inflows (Vf) to Lake Eildon

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
(Vf) (GL)	2785	2786	2782	2785	2782	2796	2802	2801	2779	2780	2776	2778

Water can be transferred into the Goulburn supply system from environmental entitlements held in the Murray or other water supply systems. Inter-Valley Transfers can also provide flows through reaches four and five in summer and can be used to meet desirable minimum flows. This reduces the need to deploy water from environmental entitlements.

There are a number of water resource management initiatives that influence the management or condition of the Goulburn River, including decisions on environmental watering. These occur at various scales and include:

Sub-catchment and catchment scale:

- Goulburn Broken Regional Waterway Strategy (GBCMA, 2014b).
- Goulburn Broken Biodiversity Strategy (Miles et al., 2010).
- State environment protection policy: Waters of Victoria (Kearns et al., 2014a).

Regional Scale:

- State environment protection policy: Waters of Victoria (Kearns et al., 2014a).
- Northern region sustainable watering strategy (NRSWS) (DSE, 2009).

State Scale:

- State environment protection policy: Waters of Victoria (Kearns et al., 2014a).
- Victorian Environmental Water Holder decisions on environmental water allocations (updated annually) (Koster et al., 2012).

National Scale:

- Commonwealth Environmental Water Holder portfolio (Lloyd, 2008).
- Murray-Darling Basin Plan (MDBA, 2014).

2.4 Related agreements, policy, plans and activities

There are a number of policies, plans, strategies and activities related to the management of environmental water in Victoria. Those with particular relevance to the Goulburn River and the management of its environmental water are listed below.

International treaties, conventions and initiatives:

- Japan Australia Migratory Birds Agreement (JAMBA) 1974.
- Convention on the Conservation of Migratory Species of Wild Animals (Bonn Convention) 1979.
- China Australia Migratory Birds Agreement (CAMBA) 1986.
- Republic of Korea Australia Migratory Birds Agreement (ROKAMBA) 2002.

Commonwealth legislation and policy:

- *Australian Heritage Commission Act* 1975 (Register of the National Estate).
- *Aboriginal and Torres Strait Islander Heritage Protection Act* 1984 (Part IIA).
- *Native Title Act* 1993.
- *Environment Protection and Biodiversity Conservation Act* 1999 (EPBC Act).
- *Water Act* 2007.
- Murray Darling Basin Plan (part of *Water Act* 2007).
- *Water Amendment Act* 2008.
- A Framework for Determining Commonwealth Environmental Watering Actions 2009.

Victorian legislation:

- *Crown Land (Reserves) Act* 1978.
- *Conservation, Forests and Lands Act* 1987.
- *Flora and Fauna Guarantee Act* 1988.
- *Water Act* 1989 (Vic).
- *Heritage Rivers Act* 1992 (Vic).
- *Catchment and Land Protection Act* 1994.
- State Environment Protection Policy (Waters of Victoria) 2003.
- *Aboriginal Heritage Act* 2006 (Vic).
- *Traditional Owner Settlement Act* 2010.

Victorian policy, codes of practice, charters and strategies:

- Our Water Our Future (DSE, 2004).
- Northern Region Sustainable Water Strategy (DSE, 2009).
- Biodiversity Strategy for the Goulburn Broken Catchment, Victoria 2010-2015 (Miles et al., 2010).
- Goulburn Broken Regional Catchment Strategy (GBCMA, 2012).
- Victorian Waterway Strategy (DEPI, 2013).
- Goulburn Broken Waterway Strategy (GBCMA, 2014b).

3. Hydrology and system operations

3.1 River Hydrology

Prior to European settlement flows in the Goulburn River would have been seasonally variable. The Goulburn would have flooded in the winter and spring however this water is now trapped in Lake Eildon causing winter flows to be low. The storage and release of water in Lake Eildon has significantly altered the hydrology of the Goulburn River, filling in winter to spring and releases to meet irrigation and consumptive demand mean that high flows in the mid Goulburn River now occur in summer to autumn. Below Lake Eildon flows increase progressively due to tributary inflows. The natural seasonal flow pattern is partially retained below Goulburn Weir (where water is diverted to meet demands), but is substantially reduced in volume from natural conditions (GBCMA, 2007).

3.1.1 Surface water

Downstream of Lake Eildon a number of tributaries contribute to flows that reach the Goulburn Weir. From Goulburn Weir a large volume of water is diverted to Waranga Basin for consumptive uses, with some passed downstream. Below Goulburn Weir to the Murray River the main tributaries are Sevens Creek and Broken River. Figure 3 shows the longitudinal profile of the river, its inflows and diversions.

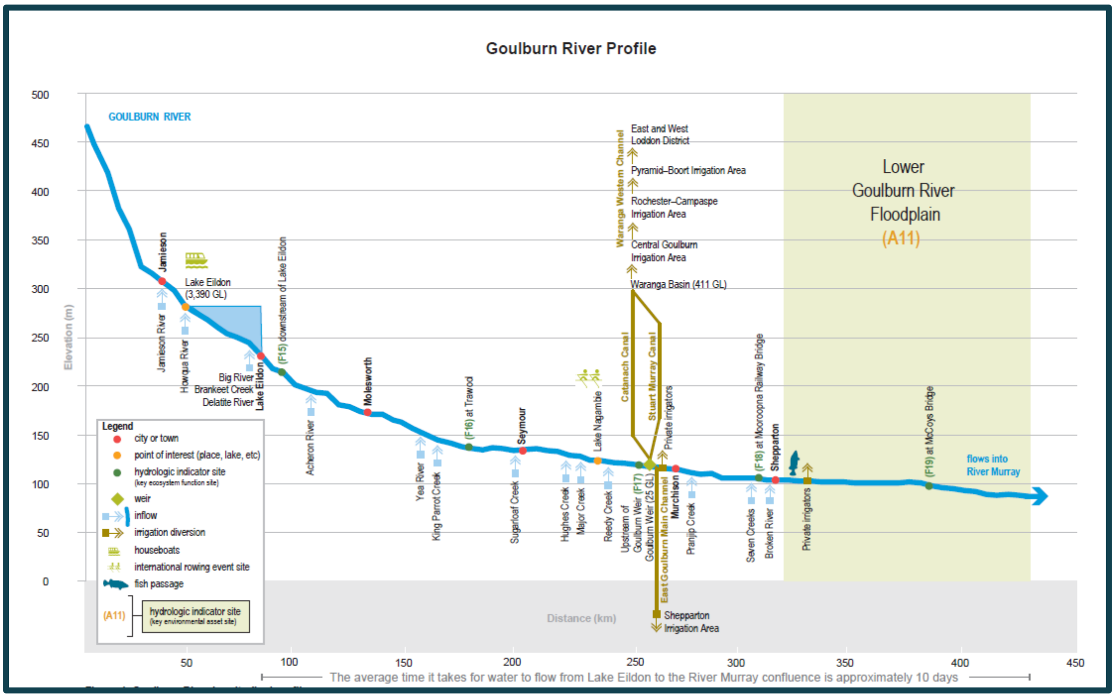


Figure 4: Longitudinal profile of the Goulburn River showing its inflows and diversions.

(Source: www.mdba.gov.au)

During the early 2000s to late 2010, Victoria experienced the millennium drought, during which time the Goulburn River was severely flow stressed, particularly between Goulburn Weir and the Murray River. This was followed by extremely wet conditions in 2010-2011 where all environmental flow objectives were met by natural catchment run-off.

3.1.2 Groundwater surface water interaction

Groundwater resources in the Goulburn Broken catchment are managed by Goulburn-Murray Water, in line with the requirements of the *Water Act (1989)* and associated policy. Goulburn-Murray Water has been delegated responsibility for licensing bore construction and the take and use of groundwater, and leads the development and implementation of groundwater management plans.

Groundwater management plans were historically developed to manage areas of intensive groundwater use, designated as Water Supply Protection Areas (WSPAs). These statutory plans were developed by a ministerially appointed committee (including representation from GB CMA) and endorsed by the Minister for Water.

More recently, Goulburn-Murray Water has been developing groundwater local management plans. The plans typically cover areas of less intensive groundwater use, referred to as groundwater management areas (GMAs). Local management plans are developed in consultation with a stakeholder and community reference group and are endorsed by Goulburn-Murray Water.

Groundwater management plans take into account the potential impact of groundwater extraction on streams, springs, wetlands and other Groundwater Dependent Ecosystems (GDEs).

State policy and guidance on groundwater planning and licensing matters is provided by the Department of Environment, Land, Water and Planning. Key policy documents include the *Northern Region Sustainable Water Strategy* (DSE, 2009), and the *Groundwater Framework for Victoria* (DEPI, 2012).

Groundwater management arrangements in the Goulburn Broken catchment are subject to the requirements of the '*Basin Plan'*. Under the *'Basin Plan*', water resource plans must be developed by 2019.

On average current groundwater use represents 10 per cent of total water use and 16 per cent of total water use in years of lowest surface water diversions (Earl, 2011b).

Surface-Groundwater connection mapping indicates the Goulburn River is gaining along most of its length, but losing over two sections – upstream of the Goulburn Weir and downstream of Loch Garry (Earl, 2011b)

Groundwater – Surface Water Interactions, Goulburn River

Where groundwater levels are higher than the surface water level, groundwater can contribute to surface water flow, playing an important role in maintaining base flows during low flow periods.

Where groundwater levels are lower than the surface water level, there is the potential for surface water to leak into the groundwater system, recharging the local aquifer.

In the Goulburn River catchment the connection between groundwater and the Goulburn River varies from the upper to the lower reaches depending on local geology and groundwater levels. Releases from storages as well as diversions along the river also influence the role groundwater plays in river flows.

Groundwater in the mid Goulburn, from Eildon to Seymour, occurs predominantly in the bedrock aquifer, moving through rock fractures and the shallow weathered profile. Groundwater in this aquifer typically discharges to either the Goulburn River or its tributaries relatively quickly after recharge, resulting in high baseflow conditions in this area (Davies et al., 2008). Long-term average baseflow between Eildon and Trawool (and included tributaries) is approximately 245–460 ML/day (DEPI, 2012).

There is a noticeable change in groundwater-surface water interaction as the Goulburn River flows into the broad alluvial plain downstream of Seymour. Baseflow downstream of Seymour is seasonally variable, with surface water recharging groundwater during high flows and groundwater discharging to the river during low flow periods (GMW, 2014). An exception to this is at the Goulburn Weir where artificially high surface water levels induce losses from the River to the aquifer (GMW, 2014).

High water tables north of Murchison increase baseflow from the shallow aquifer to the lower reaches of the Goulburn River (Murchison to the Murray River) (DEPI, 2013). The exception is from Loch Garry to McCoys Bridge where salinity management schemes and higher groundwater usage have lowered the water table below the river stage height.

3.2 System operations – history of use

Discharge in the Goulburn River is measured at six established gauging stations in the river from Lake Eildon to the Murray River (Table 3). Water levels are also measured at Lake Eildon and Goulburn Weir.

Table 3: Victorian Water Quality Monitoring Network flow gauging stations along the Goulburn River

Station number	Name
405203	Goulburn River at Lake Eildon
405201	Goulburn River at Trawool
405202	Goulburn River at Seymour
405200	Goulburn River at Murchison
405204	Goulburn River at Shepparton
405232	Goulburn River at McCoys Bridge

3.2.1 Water Management and delivery

Goulburn Weir was constructed between 1887 and 1891 across the Goulburn River near Nagambie. It was the first diversion structure built for irrigation development in Australia. The weir raises the level of the Goulburn River allowing water to be diverted by gravity via the Stuart Murray and Cattanach Canal for off river storage in the Waranga Basin (Cottingham et al., 2007).

Lake Eildon (originally known as Sugarloaf Reservoir) was constructed between 1915 and 1929 to provide irrigation water in the Goulburn Valley. The dam was modified in 1929 and again in 1935 to increase its storage capacity. However this was still inadequate to provide the Goulburn Valley with sufficient water during drought. In 1951 the construction of a large dam (now known as Lake Eildon) began. This was completed in 1955 and supplies approximately 60 per cent of water to the Goulburn Murray Irrigation District (Cottingham et al., 2014b).

Approximately 96 per cent of the water diverted from the Goulburn Murray Irrigation District is delivered to water entitlement holders for irrigation or environmental purposes. The remaining 4 per cent is supplied to urban water authorities for domestic water supply (Cottingham et al., 2014b).

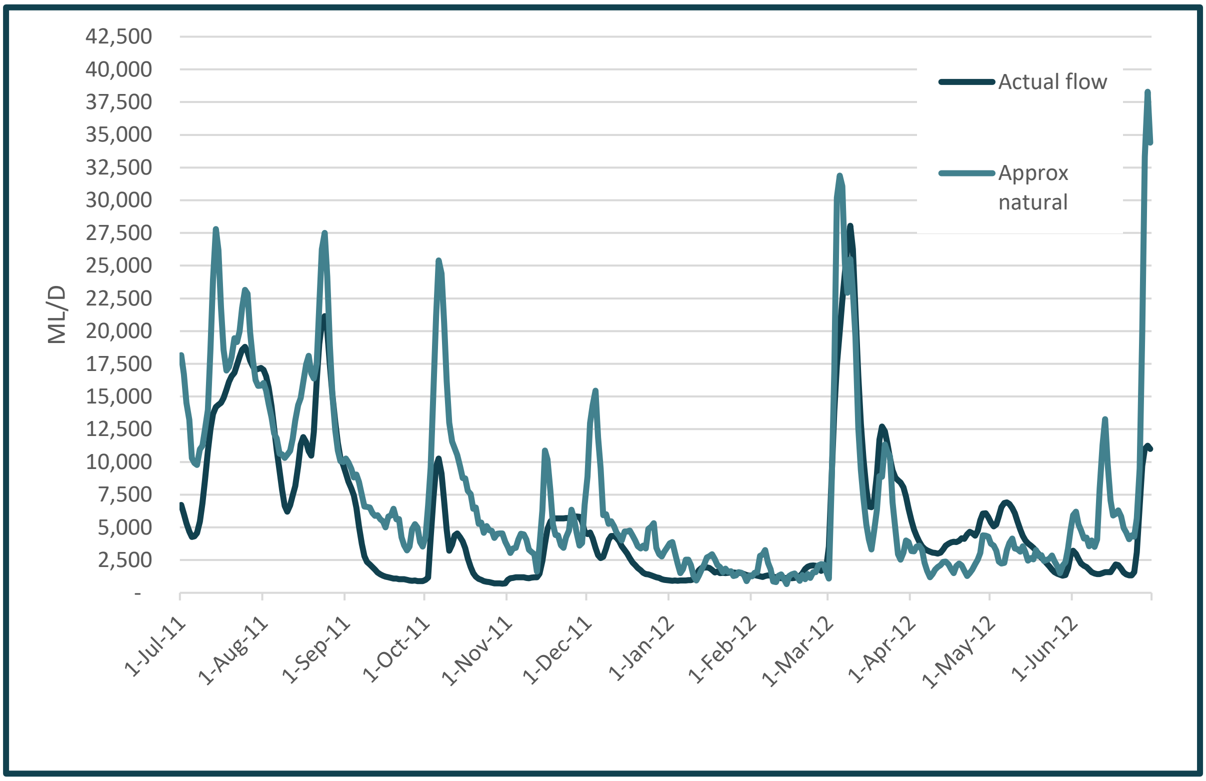
3.2.2 Environmental Watering

Goulburn River environmental water entitlements began in 1995 through the Bulk Entitlement for the Goulburn System consolidated in May 2012 (refer to Table 2).

Environmental water use in the Goulburn River has been focused on delivery in the lower Goulburn (reaches four and five). Below lists the uses of water since the first delivery in 2011-2012.

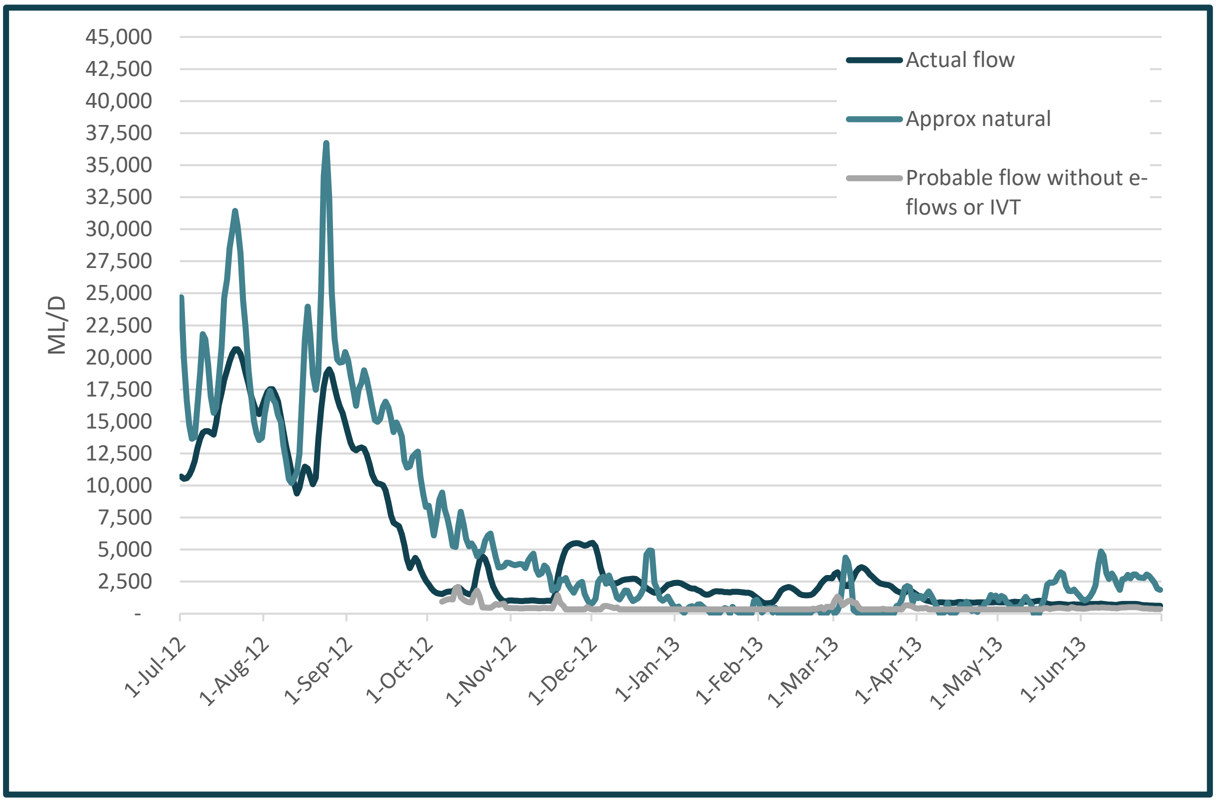
2011- 2012

- Environmental flows were used to provide a minimum flow of 830 ML/day at Murchison from late October. These flows were used to provide habitat for macroinvertebrates.
- A spring fresh was delivered in November of 5600 ML/day for 14 days for native vegetation.
- Inter-Valley Transfers commenced in early January and provided flows from 1000 ML/day to 2200 ML/day until late February.
- In March, after widespread and heavy rainfall, flood flows occurred (up to 35 000 ML/day at Shepparton) inundating the majority of the floodplain. A black water event with low dissolved oxygen levels occurred, but there were no fish deaths. With Lake Eildon above the May 2012 pre-release target, GMW commenced pre-releases and flows in the lower Goulburn were maintained at 6000 to 10 000 ML/day from March to early May.



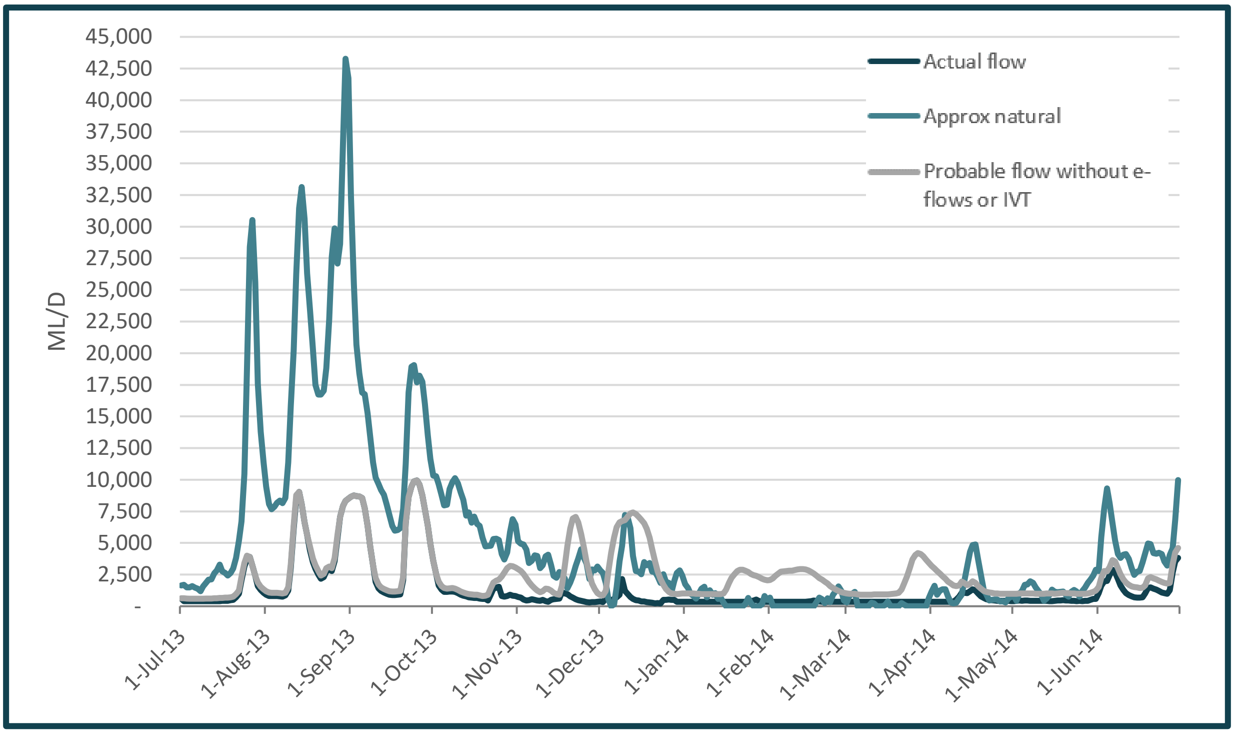
2012-2013

- Environmental water releases and Inter-Valley Transfers were used to maintain minimum flows (830 ML/day) to provide habitat, food sources and maintain a suitable water quality for macroinvertebrates.
- Provide spring freshes in October (4500 ML/day for less than 14 days) for large bodied native fish spawning.
- Fresh in November (5600 ML/day for 14 days) for removal of terrestrial vegetation and re-establishment of amphibious and lower bank vegetation.
- Fresh in March for removal of terrestrial vegetation and re-establishment of amphibious and lower bank vegetation.
- Provide higher than minimum flows from December to mid-May (for transfers to the Murray River).
- Environmental water was used to provide minimum flows to the end of June 2013.



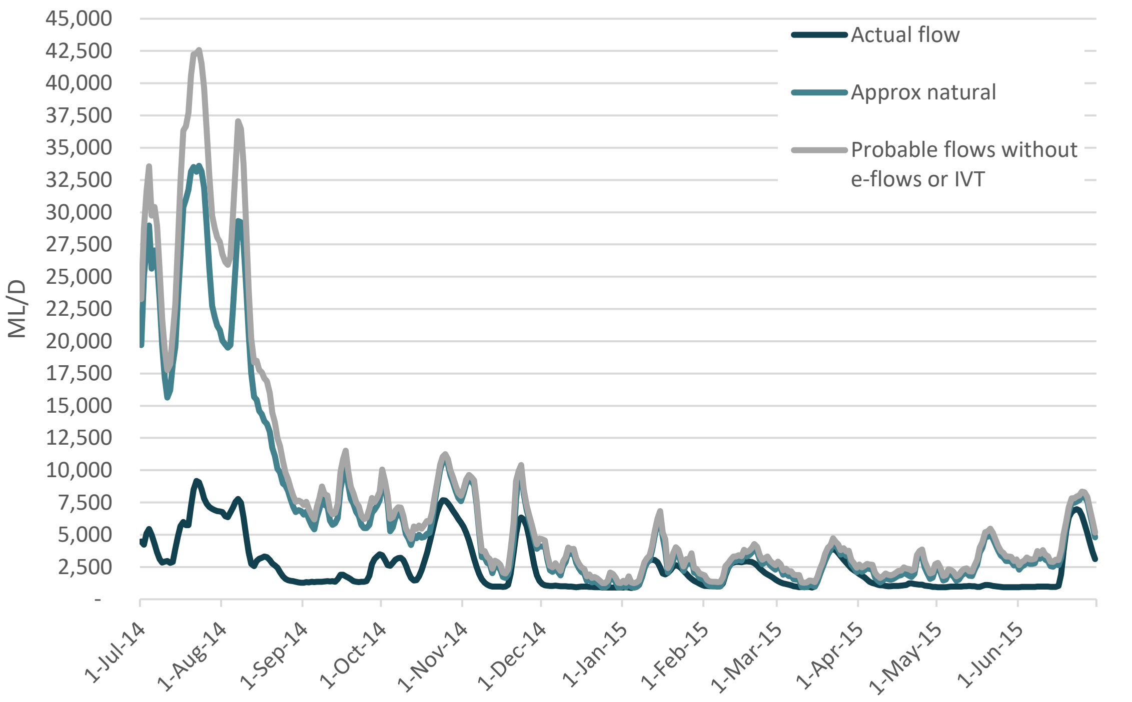
2013-2014

- Environmental watering maintained minimum flows (540 ML/day) (at lower level until October, and then higher level 830 ML/day) to provide suitable habitat for native fish and macroinvertebrates.
- Freshes in November (11 days peaking at 7800 ML/day) for large bodied native fish spawning.
- Fresh in December (22 days peaking at 7000 ML/day) for removal of terrestrial vegetation and re-establishment of amphibious and lower bank vegetation.
- Fresh in March (peaked at 4500 ML/day for 2 days) for removal of terrestrial vegetation and re-establishment of amphibious and lower bank vegetation.
- Inter-Valley Transfers (and releases to downstream environmental demands) provided increased flows in October, and consistent flows around 2500 ML/day from mid-January to late February.
- Minimum flows continue to June 2014.



2014-2015

- Environmental watering has maintained minimum flows (540 ML/day) (at lower level until October, and then higher level 830 ML/day) to provide suitable habitat for native fish and macroinvertebrates.
- Fresh in October (25 days peaking at 7500 ML/day) for removal of terrestrial vegetation and re-establishment of amphibious and lower bank vegetation.
- Freshes in November (14 days peaking at 8500 ML/day) for large bodied native fish spawning.
- Fresh in March (peaked at 4500 ML/day for 2 days) for removal of terrestrial vegetation and re-establishment of amphibious and lower bank vegetation.
- Inter-Valley Transfers (and releases to downstream environmental demands) provided increased flows in October, and two peaks of 3000 ML/day in January and February.
- Minimum flows continue to April 2015.
- Fresh in June (peaking at 8000 ML/day).



4. Water Dependent Values

4.1 Environmental Values

The Goulburn River and its associated floodplain and wetland habitats support intact river red gum forest, and numerous threatened species such as Murray cod, Trout cod, Macquarie perch, and Eastern Great Egret. Appendix 1 details the significant flora and fauna of the Goulburn River.

4.1.1 Listings and significance

The legislation, agreements, conventions and listings that are relevant to flora and fauna found along the Goulburn River and its wetlands and floodplains are listed in Table 4.

Table 4: Legislations, agreements, conventions and listing relevant to the site, or species recorded along the Goulburn River

Legislation, Agreement or Convention	Jurisdiction	Species
Japan Australia Migratory Bird Agreement (JAMBA)	International	Migratory birds
China Australia Migratory Bird Agreement (CAMBA)	International	Migratory birds
Republic of Korea Australia Migratory Bird Agreement (ROKAMBA)	International	Migratory birds
Bonn Convention	International	Migratory fauna
Environmental Protection and Biodiversity Conservation Act (1999)	National	Fauna and flora
Flora and Fauna Guarantee Act (1988)	State	Fauna and flora
DELWP Advisory lists	State	Fauna and flora

4.1.2 Mid Goulburn River

Vegetation

In-channel vegetation in reach one of the mid Goulburn River is in good condition with many macrophytes growing on the lower banks and the gravel bed. Some sites are characterised by high species richness, however there is considerable variability from site to site. These in-channel macrophytes provide habitat for macroinvertebrates and small fish and act as seed source/fragments for connected wetlands and downstream environments. It is interesting to note that this abundance is in contrast to observations made in 2003 where macrophyte presence was scarcer. It is believed the lower, shallower flows that have occurred in the last six to ten years have allowed macrophytes to establish (Cottingham et al., 2014a). Downstream of reach one, there are smaller, less abundant and less diverse patches of macrophytes. Limitation of light availability is thought to be the reason for the lack of macrophytes in reaches two and three.

The mid Goulburn River retains an almost continuous riparian canopy although the width of the riparian zone is generally narrow (e.g. one to a few trees wide). Riparian vegetation is dominated by the EVC 56: Floodplain Riparian Woodland (refer to issues paper by Cottingham et al. 2014). This EVC occurs along each reach and is characterised by a canopy layer dominated by two species of Eucalypt: *Eucalyptus camaldulensis* (River Red Gum) and *Eucalyptus melliodora* (Yellow box). The EVC is listed as 'endangered' or 'vulnerable' in two bioregions (Central Victorian Uplands and Victoria Riverina) as vegetation clearing for agriculture has reduced the pre-European cover of EVC 56 along the river considerably, and it is often narrower and much less continuous than in pre-European times [1] (Cottingham et al., 2014a).

Macroinvertebrates

Macroinvertebrate populations in the mid Goulburn River are in poor condition according to the Sustainable Rivers Audit (refer to Section 5.1 – Current Condition). An assessment of Macquarie perch in the Goulburn River conducted by the Department of Environment and Primary Industries in 2014 found that lower food availabilities for fish such as shrimp occurred throughout the mid Goulburn (Kearns et al., 2014b).

Fish

A fish survey was conducted of the mid Goulburn River (primarily reaches 2 and 3) in May 2014 that showed the most abundant native fish was Australian smelt and the most abundant non-native fish was carp (Cottingham et al., 2014a). Large bodied natives of note in the mid Goulburn are Murray cod, Macquarie perch, Golden perch and Freshwater catfish. There were low abundances of flood dependent and floodplain specialist species which may be a reflection of the survey method (electrofishing), and/or a result of the lack of connection to floodplains and their wetlands. Below Lake Eildon, reach one has a large trout population supported by the cold water releases from the dam.

Overall the mid Goulburn River is recognised as a heritage river (under the *Heritage River Act* 1992), and for the presence of threatened fish species (e.g. Murray cod, Macquarie perch) and vulnerable vegetation classes, which are high value assets whose protection is addressed in management planning (Cottingham et al., 2014a).

[1] Based on comparison of the 2005 vegetation layers and modelled 1750 layers

4.1.3 Lower Goulburn River

The Lower Goulburn River and floodplain (Figure 5) provide a variety of key habitats including a network of 'flood runners' and wetlands (both permanent and ephemeral). These ecosystems support important species and habitats that are listed in international and national agreements (GBCMA, 2010).

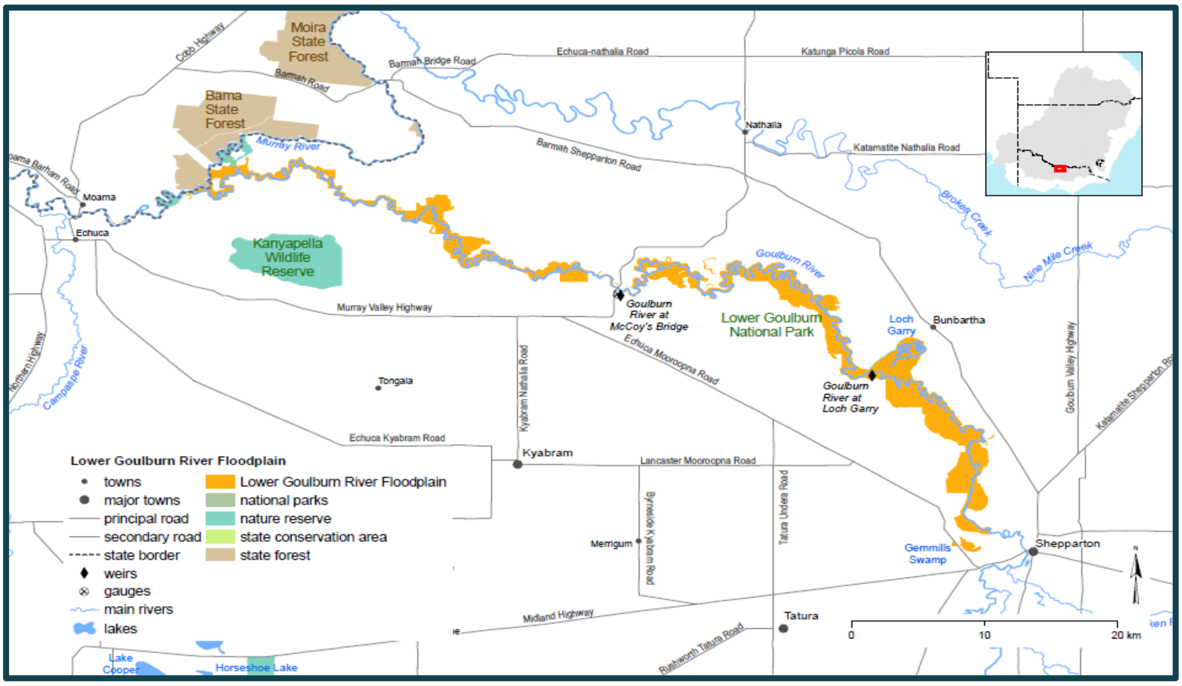


Figure 5: Lower Goulburn River Floodplain

Vegetation

Cottingham et al. (2011) recorded 32 EVCs along the lower Goulburn. Eleven wetland EVCs, 13 floodplain EVCs and eight terrestrial EVCs. Thirteen of these EVCs are classified as flood dependent (Refer to Appendix 2).

Fish

The Lower Goulburn River supports a variety of large and small bodied native fish species including Murray Cod, Golden perch, Trout Cod, and Silver perch. However, small bodied native fish were the most abundant including Australian smelt and Murray-Darling rainbowfish. European Carp are also abundant in the Goulburn River.

A key ecological objective of environmental water management in the Goulburn River is to stimulate Golden and Silver perch spawning as they require flow variations as a spawning cue. Figure 6 shows fish larvae collected during sampling of the lower Goulburn River in November 2014. Murray cod and a number of other native fish species spawn annually in the lower Goulburn regardless of flow levels (GBCMA, 2013).

Figure 6: Fish larvae (small clear balls) in collected from the Goulburn River in November 2015

Waterbirds

Waterbird breeding has been recorded within wetlands of the lower Goulburn. Appendix 1 lists the significant species. Species such as the EPBC listed Australasian bittern use the river as a breeding and feeding site. However, the breeding requirements of water birds are currently not met using environmental flows due to the inability to provide overbank flows to water bird breeding sites such as wetlands and the floodplain.

4.2 Ecosystem Functions

'Ecosystem function' is the term used to describe the biological, geochemical and physical processes and components that take place or occur within an ecosystem. Ecosystem functions relate to the structural components of an ecosystem (e.g. vegetation, water, soil, atmosphere and biota) and how they interact with each other, within ecosystems and across ecosystems (GBCMA, 2014c). Ecosystem functions critical to support the primary water dependent environmental values of the Goulburn River include (but are not limited to):

Food production – a critical ecosystem function is the conversion of matter to energy for uptake by biota. Structural components include substrate surfaces (e.g. instream-woody habitat, rocks and gravel) for biofilms, and plant matter. Interactions between primary producers and consumers such as zooplankton and macroinvertebrates which break down the carbon and nutrients required for higher order consumers. The Goulburn River has extensive instream woody habitat within the river channel. This provides substrate for biofilm growth and food and habitat for macroinvertebrates and small fish. Slack water habitats are also favourable planktonic production areas.

Delivering freshes down the Goulburn in winter and spring assist with moving accumulated organic matter from the lower banks and benches into the river system. This assists with food production and also reduces the amount of carbon entering the river system during higher flows in the warmer months. This prevents black water (low dissolved oxygen) events occurring in the river.

Reproduction – recruitment of species is important for the river's primary values, native fish and flora. Native fish require nursery habitats such as slack water areas to provide suitable conditions for larval metamorphosis (linked to food web function). Breeding is required in most years for small bodied fish in particular, and it is recommended that conditions are provided for large bodied fish in most years. The link of the Goulburn River to other rivers is important for fish movement, recruitment and breeding especially for larger bodied threatened fish species such as the Murray cod, trout cod and golden and silver perch. These species migrate for breeding; moving to either the Broken River or the Murray River. Slack water habitats across a range of low flow magnitudes are critical habitat for fish larvae.

Native flora – especially Red Gums, require high flows in spring to facilitate germination events. Follow-up watering is required in the second year to water germinated saplings. Ecological vegetation classes that are listed along the riparian zone of the river are important as food, breeding and roosting sources for fauna.

Dispersal – movement of individuals throughout the river is linked to the function of the food web. By providing variable flows, different areas of the river are accessible for fish and other aquatic fauna for food and in various life stages. Flow connectivity also facilitates dispersal of juveniles to other areas within the river or to other river systems. The river provides a corridor for fish passage but also for species that rely on the riparian vegetation as a corridor along the river bank.

The Basin Plan specifies the need to 'identify priority environmental assets and priority ecosystem functions, and their environmental watering requirements' and section 8.50 outlines the method for identifying ecosystem functions that require environmental watering and their environmental watering requirements (*Schedule 9 – Criteria for identifying an ecosystem function*). The Goulburn River's ecosystem functions that meet the assessment indicators are described in Appendix 3.

4.3 Social Values

The Goulburn River is a highly valued water-way in the Goulburn Broken Catchment. Its traditional owners, local communities and visitors value its recreational, cultural and social aspects. The river supports numerous land management practices and assists with tourism to the region.

4.3.1 Cultural Heritage

The Traditional Owners of the Goulburn Broken Catchment remain connected to and feel a strong affinity with Country, including the land, waterways, wetlands and local ecology. Traditional Owners in the north of the Catchment are Yorta Yorta Nation, whose traditional lands include the northern plains of the Goulburn and Murray Rivers. Yorta Yorta Nation is defined by eight clan groups: Moira; Kailtheban; Wollithiga; Nguaria-iiliam-wurrung; Ulupna; Kwat Kwat; Bangerang and Yalaba Yalaba (Webb et al., 2014).

The south of the Catchment forms part of the traditional lands of Taungurung Clans, which includes the mountains and rivers to the Great Divide. Taungurung Clans is defined by nine clans: Buthera Balug; Look William; Moomoom Gundidj; Nattarak Balug; Nira Balug; Warring-Illum Balug; Yarran-Illam; Yeeren-Illam-Balug and Yowung- Illam Balug (GBCMA, 2015).

The Yorta Yorta Nation Aboriginal Corporation (YYNAC) and Taungurung Clans Aboriginal Corporation (TCAC) are both Registered Aboriginal Parties (RAPS), under the *Aboriginal Heritage Act 2006* (Vic)[2].

4.3.2 Recreation

Recreational angling, sight-seeing and passive recreation are the major waterway uses in the upper reaches of the Goulburn River, its tributaries and Lake Eildon. A survey of recreational anglers (2012), found the Goulburn River was voted the most popular recreational fishing river in Victoria.

In the mid Goulburn River high social values include fishing, species of local significance and passive recreation. The maintenance of Goulburn Weir – Lake Nagambie is also an important recreational and social amenity and provides tourism for both the township of Nagambie and has a large rowing facility on its foreshore. The lower Goulburn high social values as determined by the RiVERS database include boating, wakeboarding, water skiing, canoeing, and camping (either seasonal or throughout the year).

4.4 Economic Values

The Goulburn River supports a diverse range of enterprises. These include agriculture in the mid Goulburn River reaches and irrigated agriculture in the lower Goulburn River reaches. Primary industries include dairy, horticulture, viticulture, livestock production, cropping, timber production, market gardens and aquaculture. Tourism also plays a major part along the Goulburn River. The Goulburn River harnesses and supplies water for irrigation, urban and environmental purposes by Lake Eildon and the Goulburn Weir. This water underpins the economic and social wealth of the region (GBCMA, 2014b).

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2 The Victorian *Aboriginal Heritage Act* 2006 (the Act) recognises Aboriginal people as the primary guardians, keepers and knowledge holders of Aboriginal cultural heritage. At a local level, Registered Aboriginal Parties (RAPs) are the voice of Aboriginal people in the management and protection of Aboriginal cultural heritage.

RAPs have responsibilities relating to the management of Aboriginal cultural heritage under the Act. These include evaluating Cultural Heritage Management Plans, providing advice on applications for Cultural Heritage Permits, decisions about Cultural Heritage Agreements and advice or application for interim or ongoing Protection Declarations

4.5 Conceptualisation of the site

Conceptual models have been developed that represent how a particular ecological component will respond to flow manipulation. A range of conceptual diagrams for specific components targeted by delivery of environmental flows in the Goulburn River are included below in Figures 7-10. These were developed for the Victorian Environmental Flows Monitoring and Assessment Program and are general models rather than specifically populated for the Goulburn River. These conceptual diagrams represent the level of understanding of flow dynamics with various ecological components at the time of their development. They are based on environmental flow objectives from various studies and catchments and not all components targeted by environmental flow delivery in the Goulburn River are included here.

The source for all these conceptual diagrams and explanations is "Victorian environmental flows monitoring and assessment program – Monitoring and evaluation of environmental flow releases in the Goulburn River" (Chee et al., 2006).

Figure 7 represents the geomorphogical response of a river to flow; with the main flow related drivers of change being magnitude and duration, and frequency of high flows, and sediment load of the river. These drivers then interact with various response times and result in changes to the channel bed, width and stability.

Figure 8 represent generalised habitat processes on a reach scale and focuses on maintenance of hydraulic habitats for fish, invertebrates and vegetation. The conceptual model looks at two flow types; summer autumn low flows, and winter spring baseflow and freshes.

The conceptual diagram in figure 9 shows the relationships between spring and summer flows and their interaction with seed germination, habitat maintenance and seasonal growth.

The final conceptual diagram presented in figure 10 shows very general interactions between year round river flows with fish habitat and spawning.

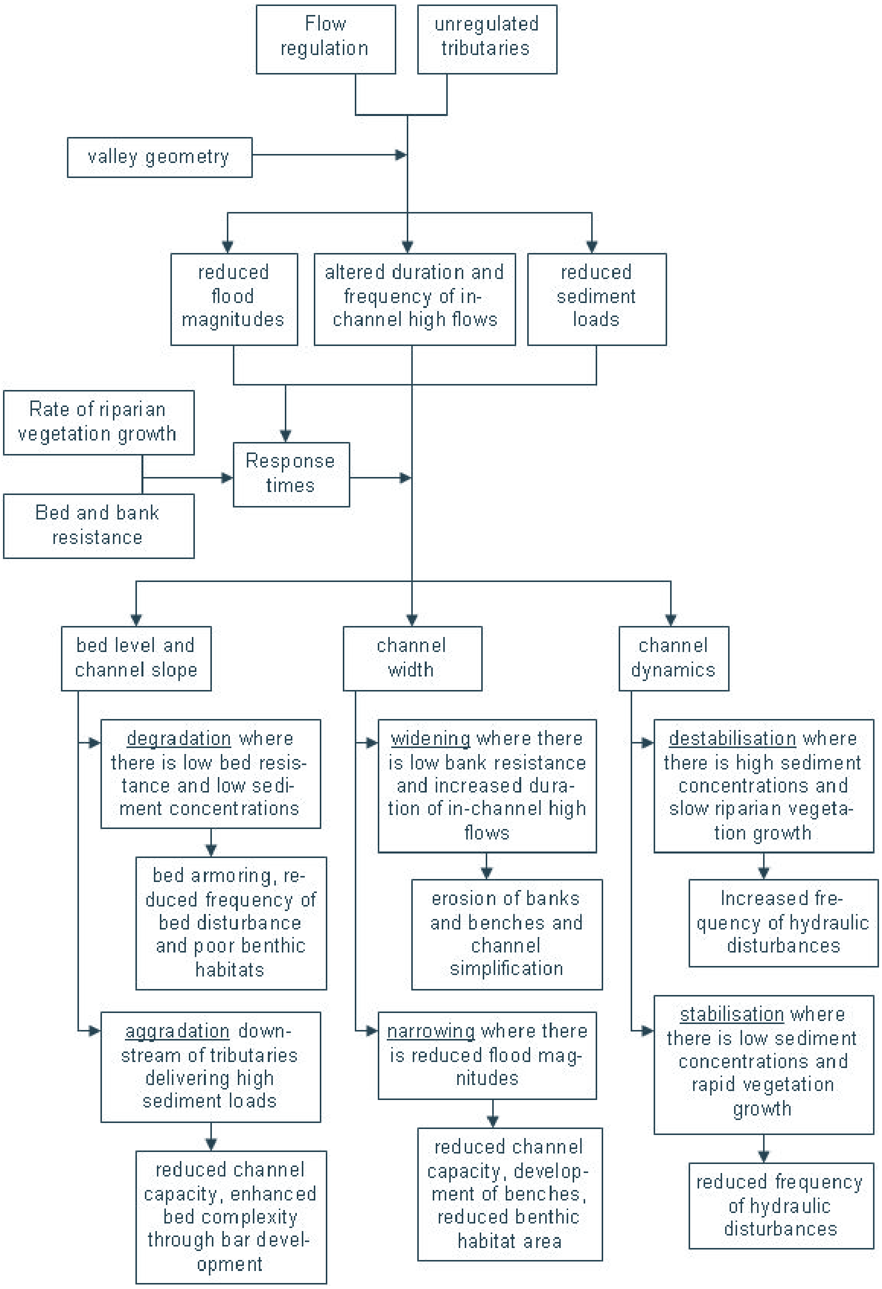

Figure 7: Conceptual model of geomorphic responses to flow regulation

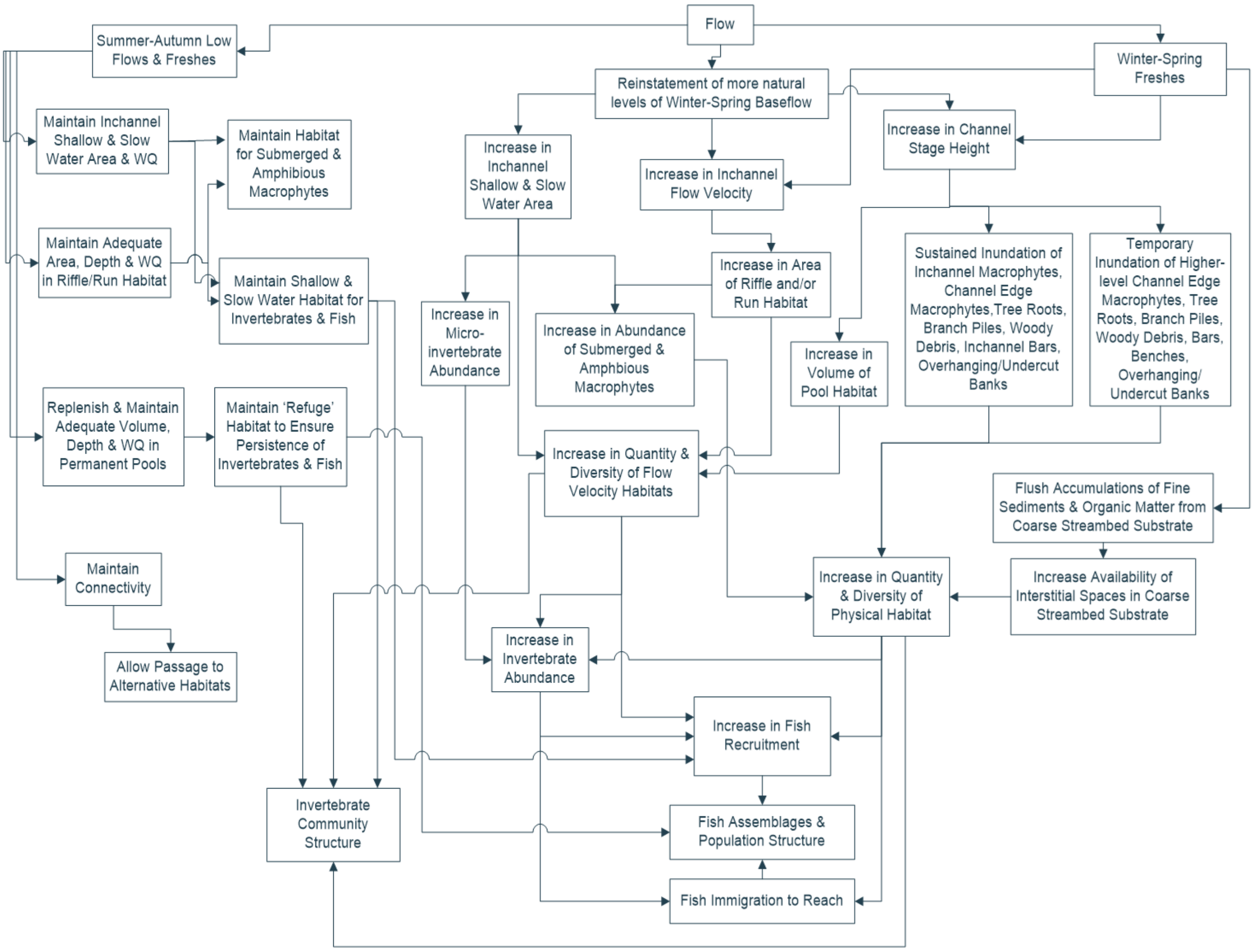

Figure 8: Conceptual model of habitat processes

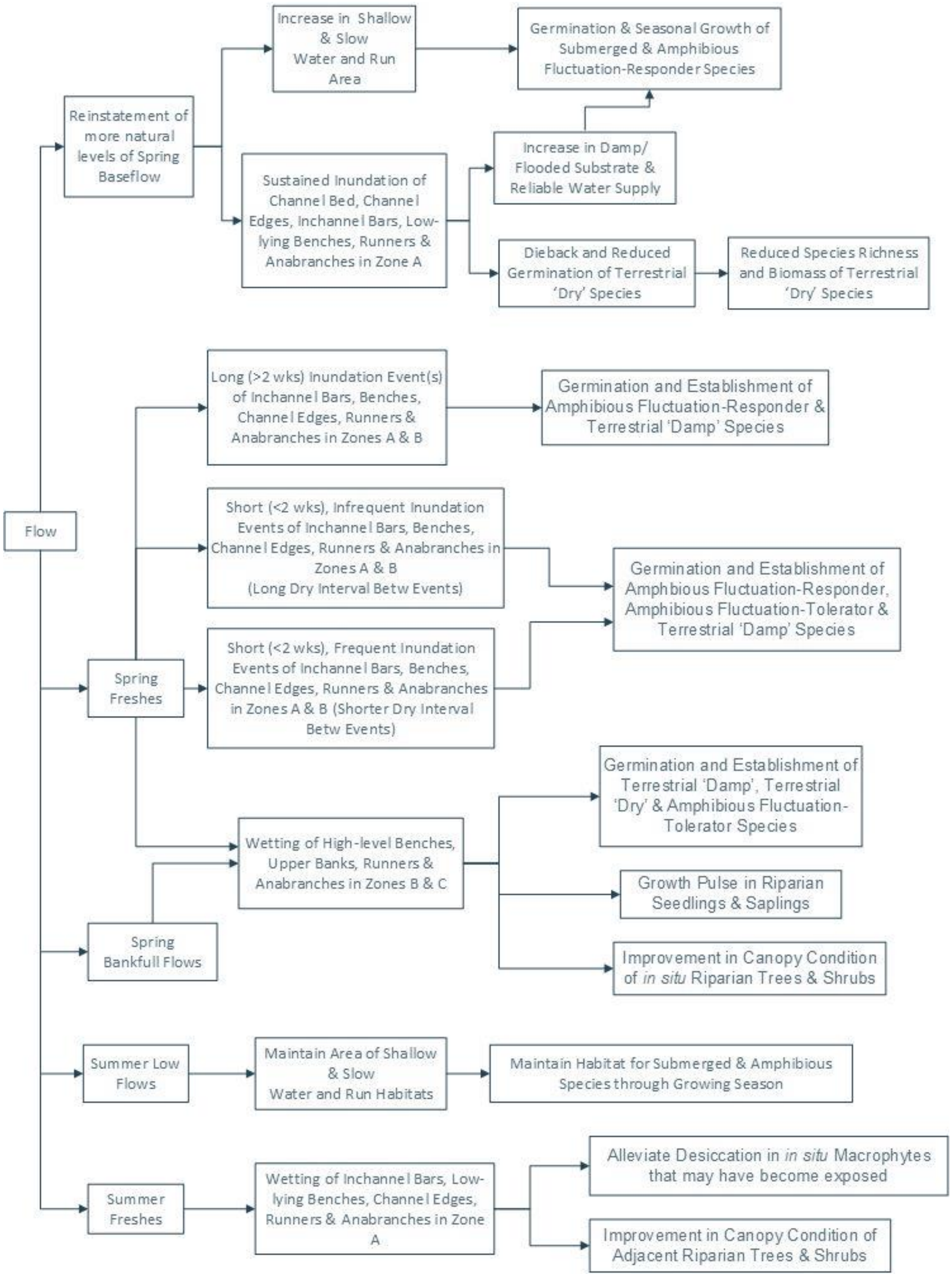

Figure 9: Conceptual model of aquatic and riparian vegetation responses to spring and summer flows.

Zone A: from mid-channel to stream margin (or the area covered by water during times of baseflow); Zone B: from stream margin to a point mid-way up the bank (or the area that is infrequently inundated): Zone C: from mid-way up the bank to just beyond the top of the bank

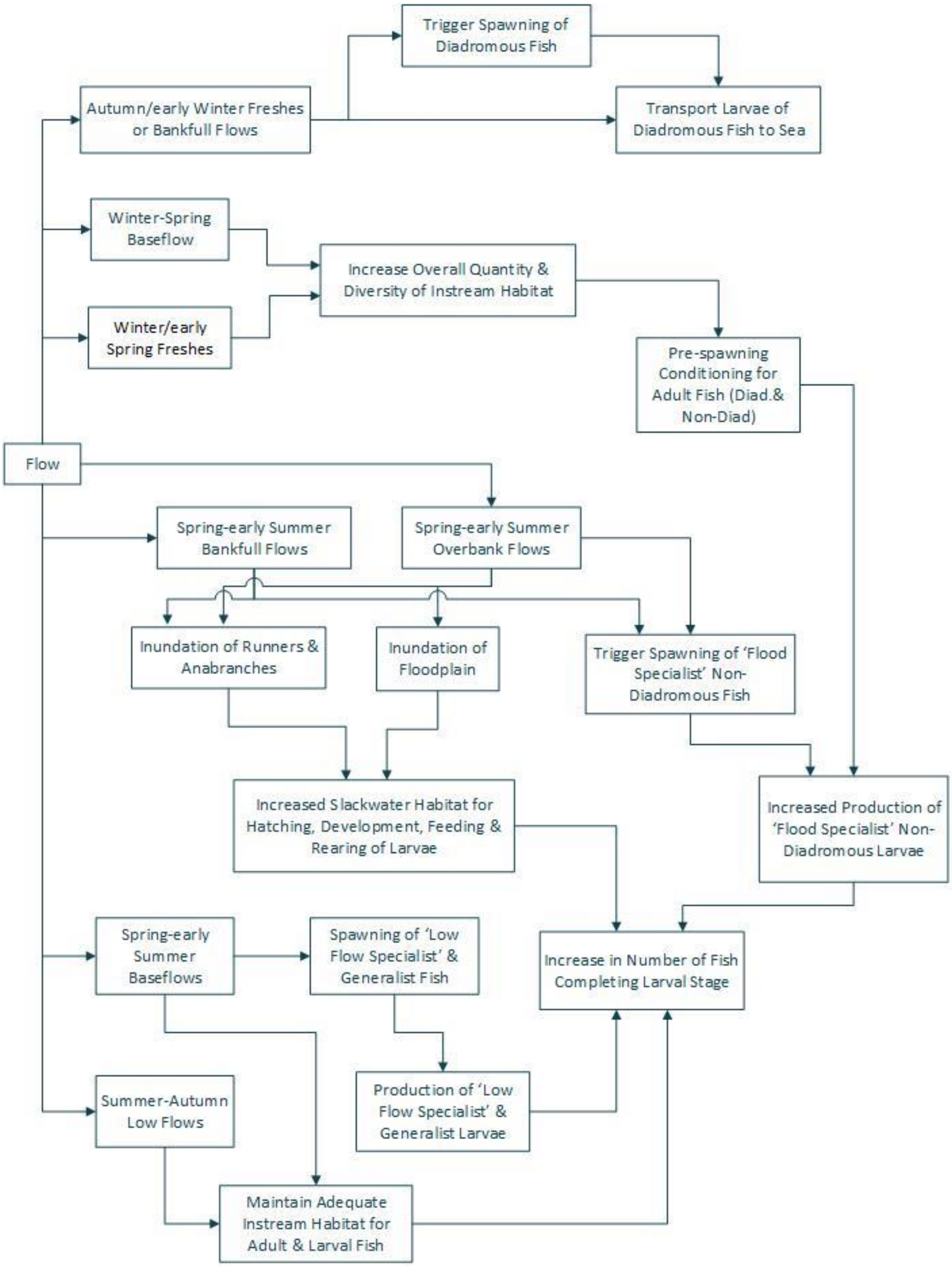

Figure 10: Conceptual model for fish spawning and recruitment into the juvenile population.

5. Ecological Conditions and Threats

5.1 Current Condition

Over the last twenty years, conditions in the Goulburn catchment have been quite dry. After two wet years between 1995 and 1997, there were thirteen years that were drier than average (including eight very dry years). In 2010 the drought broke with a very wet year. 2011-2012 and 2012-2013 were drier than average, and the following two years (2013-2014 and 2014-2015) were very dry (Cottingham et al., 2013).

The 2014 Mid Goulburn River flows study (Cottingham et al., 2014b) provides a good description of current ecological conditions of the river from Lake Eildon to Goulburn Weir. The river is described as an 'anabranching channel frequently confined by bedrock and valley walls'. The bed consists of gravels between Lake Eildon and Seymour, and changes to sand between Seymour and Nagambie. There are numerous point bars, gravel riffles and benches in the reach. River surveys conducted as part of the 2014 flows study compared cross sections with those taken 12 years earlier and showed little evidence of large scale channel change over this time. Sediment supply to reach one (Lake Eildon to Yea River) is very restricted due to the presence of Lake Eildon, and consequently the mid Goulburn River relies on tributaries downstream of Lake Eildon for sediment input.

The water quality in the mid Goulburn River was deemed to be generally good, with the main issue being cold water pollution from Lake Eildon releases (Cottingham et al., 2014b).

Condition monitoring of the Goulburn River occurs through a number of programs across a range of scales. Some of these programs have not been assessed since the end of the drought, and therefore the condition reported may actually be different from the current condition.

- The Sustainable Rivers Audit (SRA) is the most comprehensive assessment of river health in the Murray Darling Basin. The SRA provides scientifically robust assessments of the ecological health of the basin's 23 river valleys. The Sustainable Rivers Audit is based on an assessment of fish, macroinvertebrates, vegetation, physical form and hydrology.

- The Index of Stream Condition (ISC) is a statewide assessment of river condition. ISC measures the relative health across hydrology, physical form, stream side zone, water quality and aquatic life against reference condition[3]. Assessments were done in 1999, 2004 and 2010 (Cottingham et al., 2010).

- Victorian Environmental Flow Monitoring and Assessment Program (VEFMAP) is a targeted program carried out in eight rivers in Victoria. The lower Goulburn River is one of those rivers and has annual monitoring of fish and macroinvertebrates. Every second year monitoring of vegetation occurs, and there was a once off physical habitat survey. River survey to assess channel form has been conducted twice during the monitoring program. VEFMAP monitoring commenced in 2008 and still continues. The analysis of this data is based on statistical methods rather than before-after analysis.

[3] Reference condition is an estimate of condition had there been no significant human intervention (i.e. pre-European settlement) in the landscape, providing a benchmark for comparisons.

- The Commonwealth Environmental Water Holder has recently commenced a long term intervention monitoring program in the lower reaches of the Goulburn River. The program aims to evaluate the large-scale effect of Commonwealth environmental watering, as well as specific responses in each selected area. The program is only in its first year of a five year project and preliminary results are not yet available.

Sustainable Rivers Audit

The Sustainable Rivers Audit is a systematic assessment of the health of the health of 23 major river valley ecosystems in the Murray-Darling Basin.

Sustainable Rivers Audit (SRA) 1 was the first of two audits to be conducted and occurred from 2004-2007 (Cottingham and SKM, 2011). Data collected was based on: fish, macroinvertebrates and hydrology. SRA 2 was based on data collected from 2008 to 2010 (Cottingham et al., 2007). It represents a significant advance and includes the three assessment themes in SRA 1, and physical form and vegetation. There has also been refinement of components within themes and improved data sources and analyses. This period in which SRA 2 data was collected included the severe millennium drought, and the results should be interpreted in the context of the prevailing climate conditions. Because of changes in sampling and analysis methodology, SRA 2 results should not be directly compared with those of SRA 1 (Cottingham et al., 2014b).

The Goulburn Basin was divided into three components. The Upland Zone, Slopes Zone and the Lowland Zone (Figure 11). The slope zone and the lowland zone relate to the mid Goulburn and Lower Goulburn reaches of the river. Overall ecosystem health for the Goulburn Valley River as reported by SRA 1 and 2 was in very poor health. Refer to Table 5 for scores for individual communities for SRA 1 and SRA 2. Condition assessments for each valley were related to a benchmark called a ‘reference condition’. This estimated the status of a component (for example, the value of a measure of a fish community) as it would be in the absence of significant human intervention in the landscape.

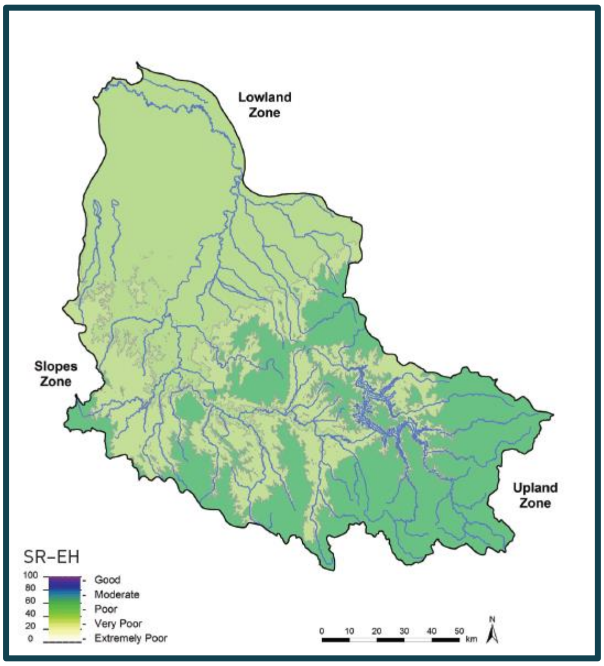

Figure 11: Goulburn Valley map with zones coloured by the SRA River Health (SR-EH) Rating.
(Davies et al., 2012)

Table 5: Sustainable River Audit indices ratings and trajectories for the Goulburn River

Parameter	SRA1 2004-2007	SRA 2 2008-2010	Change
Fish	LL = Very Poor SZ and UZ = Extremely Poor Overall = Extremely Poor	LL = Extremely Poor SZ = Extremely Poor UZ = Very Poor	LL = negative change UZ = positive change Overall = no change
Macroinvertebrates	LL = Poor SZ and UZ = Moderate Overall = Poor	LL = Poor SZ and UZ = Moderate Overall = Poor	No change
Vegetation	NA	LL and SZ = Very Poor UZ = Good Overall = Poor	NA
Physical Form	NA	LL = Moderate SZ and UZ = Good Overall = Good	NA
Hydrology	LL = Very Poor to Poor SZ and UZ = Good Overall = Poor	LL = Very Poor SZ = Moderate UZ = Good Overall = Poor	LL = negative change SZ = negative change Overall = No change
Ecosystem health rating	Very Poor Health	Very Poor Health	No change

Legend: LL = Lowland Zone, SZ = Slope Zone, UZ= Upland Zone

Index of Stream condition

The Index of Stream Condition (ISC) measures the relative health across hydrology, physical form, stream side zone, water quality and aquatic life against reference condition[4]. Assessments were done in 1999, 2004 and 2010 (Cottingham et al., 2010). The Goulburn River was assessed at 16 sites (Figure 12). The ISC reach numbering for the Goulburn River starts at the Murray River (1) and finishes at Woods Point (16). Table 6 shows the condition rating for 2010, with scores subindices for 1999 (99), 2004 (04) and 2010 (10).

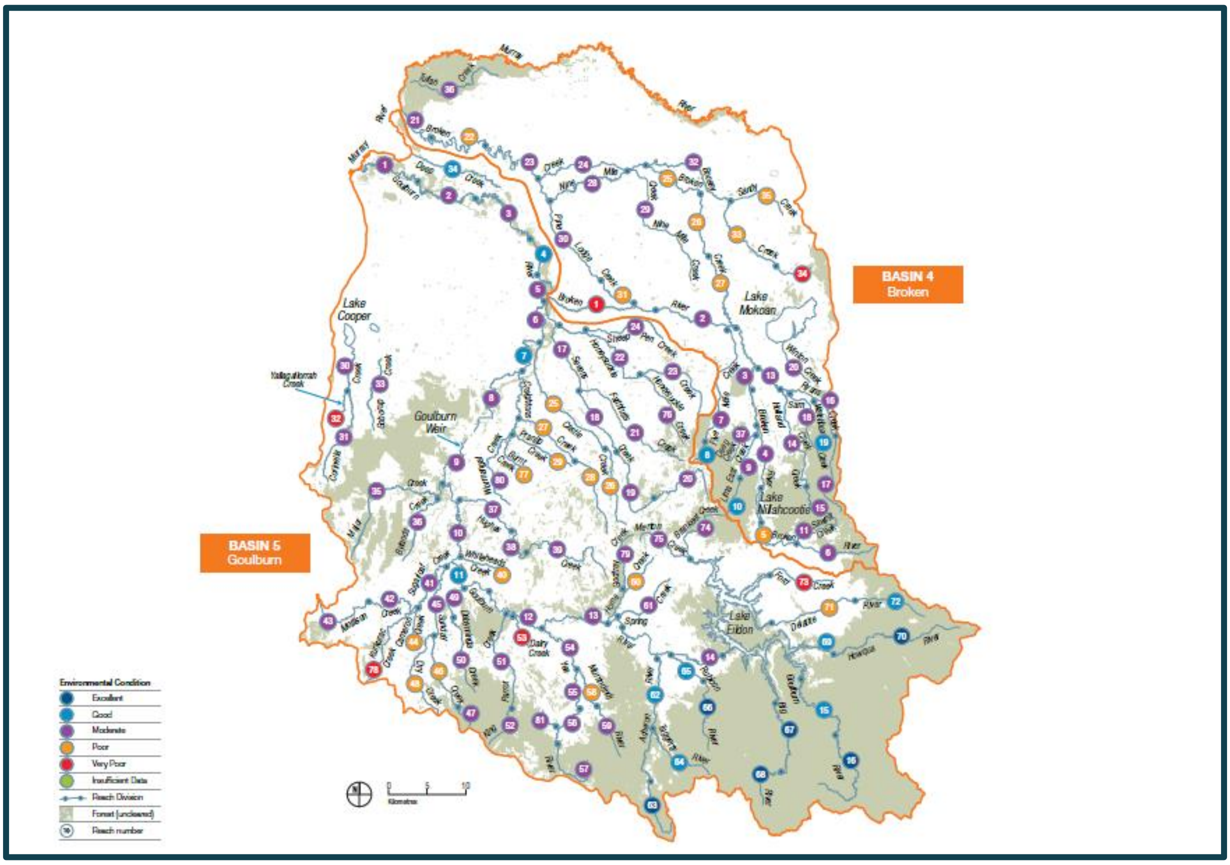

Figure 12: ISC sampling sites and environmental condition scores for rivers and streams in the Goulburn Broken Catchment

(Cottingham et al., 2010)

[4] Reference condition is an estimate of condition had there been no significant human intervention (i.e. pre-European settlement) in the landscape, providing a benchmark for comparisons.

Table 6: Index of Stream condition scores along the Goulburn River in 1999, 2004 and 2010.

ISC REACH	ENVIRO FLOW REACH	HYDROLOGY			PHYSICAL FORM			STREAMSIDE ZONE			WATER QUALITY			AQUATIC LIFE			TOTAL			CONDITION 2010
		99	04	10	99	04	10	99	04	10	99	04	10	99	04	10	99	04	10	
1	5	0	0	7	8	3	7	8	7	9	6+	6+	7		5	5	22+	15	32	MODERATE
2		0	0	7	7	3	7	8	6	8	7	6	5	6	6+	3	22	16	26	MODERATE
3		0	0	7	6	3	8	8	6	7				8	6	5	22	14	32	MODERATE
4	4	0	0	7	6	6	8	8	7	8	9+	6+			4	8	22+	18	38	GOOD
5		0	0	7	6	7	7	7	6	8	8	6	7		3	6	20	16	34	MODERATE
6		0	0	7	7	5	7	8	6	7			10	6+	5+	5	20+	16	33	MODERATE
7		0	0	7	7	4	7	8	6	8	10+	9+			5	8	24+	17	37	GOOD
8		0	0	7	8	5	4	7	7	8	9	9	10	4	5+	6	21	19	30	MODERATE
9	3	0	0	7		4	7		7	7			9		5	4	NA	15	31	MODERATE
10		0	0	7	9	3	5	7	3	7					3	5	19	9	28	MODERATE
11	2	0	0	7	5	4	7	2	2	7			7		5		8	10	35	GOOD
12		0	0	7	8	5	6	6	6	6					3		18	13	30	MODERATE
13	1	0	0	7	8	5	5	5	5	7	9+	9+			3+	3	21+	15	25	MODERATE
14		0	1	7	8	3	5	4	4	6	9	9	9	8		8	22	16	32	MODERATE
15*		10	9	9	8	4	6	8	7	9	10	10	6	10	9	8	44	34	35	GOOD
16*		10	9	9	7	5	7	4	8	9				10	9+	9	34	36	42	EXCELLENT

Source www.ics.water.vic.gov.au

**note: Reaches 15 and 16 are in the Upper Goulburn and are outside the scope of this report.*

Changes to survey methods between sampling periods makes the direct comparison of sub-index and total score data unreliable. The 2010 ISC assessment indicated that 11 of the 14 reaches were in moderate condition with 3 in good condition.

VEFMAP

A three year Australian Research Council grant was awarded to the University of Melbourne to analyse statewide Victorian Environmental Flow and Monitoring Assessment Program (VEFMAP) data. A number of specific flow based impacts/ objectives were tested in the analysis. The key findings of this work are detailed in a report by Miller et al. (2015) (THIESS, 2011) and include:

- Prolonged inundation of the river bank reduces encroachment of terrestrial vegetation and long duration events are more successful at this than multiple short events.
- There is a positive response from native vegetation to short duration wetting events in winter/spring.
- Insufficient evidence to draw conclusions regarding flows on any of the fish populations assessed.
- Unable to detect any response by macroinvertebrate assemblages to flow variations.
- The floods of 2010 and 2011 resulted in net aggradation of sediment to rivers.

Vegetation

Instream vegetation in reach one of the mid Goulburn River is in good condition with many macrophytes growing on the lower banks and the gravel bed. Some sections are characterised by high species richness, however there is considerable variability from site to site (Cottingham et al., 2014b).

In the lower Goulburn River amphibious vegetation had begun to re-establish during 2013-2014 on the lower river banks following the extended drought and subsequent floods. In 2014-2015, this vegetation remains patchy with some new growth. There are small areas below the 3000 ML/day flow level where some new vegetation has established in 2014-2015.

Photo point monitoring at a number of sites between Nagambie and Yambuna has been occurring for a number of years and show some areas of successful vegetation regeneration. At Cable Hole (just downstream of Nagambie), a patch of macrophytes (Phragmites) has been monitored and shows growth and expansion progressively over recent years as shown in Figure 13A and 13B. Overall, macrophyte abundance in the lower Goulburn River remains low. This reduces habitat diversity, which may partially account for poor macrophyte diversity in the lower Goulburn River.

Figure 13: Cable Hole photo point monitoring showing the exposure of Phragmites

Fish

Large bodied fish of note in the mid Goulburn are Murray cod, Macquarie perch, Golden perch and Freshwater catfish. A fish survey of the mid Goulburn River (primarily reaches 2 and 3) in May 2014 found that the most abundant native fish was Australian smelt and the most abundant non-native fish was carp (Cottingham et al., 2014b). The survey also found there was a low abundance of flood dependent and floodplain specialist species which may be a reflection of the survey method (electrofishing), and/or a result of the lack of connection to floodplains and their wetlands. The overall condition of native fish populations in reaches one and two was considered poor, and moderate in reach three (Cottingham et al., 2014a), based on the following:

- Species diversity and abundance.
- Observed versus expected.
- Habitat quality and riparian zone.
- The number of alien fish.

Potential threats to native fish in the mid Goulburn River are low water temperature, competition from introduced species and angling and low macroinvertebrate biomass.

Flow dependent species that are targeted in environmental water delivery in the lower Goulburn River are Golden perch. This species spawned in the lower reaches of the Goulburn River for the first time in ten years during 2010 September floods. Golden perch has since spawned in the lower Goulburn River in 2013 and 2014. In December 2010, a major black water event occurred in the lower reaches of the Goulburn River affecting the recruitment of juveniles. In 2013, the eggs/larvae were potentially exported to the Murray River as only small numbers of juveniles were detected during sampling. In 2014, hundreds of Golden perch larvae were collected between Nagambie and the confluence with the Murray River in response to an environmental water release in November. This was the first time since the 2010 floods that any larvae have been found upstream of Yambuna.

Macroinvertebrates

The macroinvertebrate population in the mid Goulburn River is considered poor with a much lower abundance of shrimp, yabbies, dragonflies and damselflies than in lower Goulburn River. The poor condition is a factor of low water temperature, altered flow regime and hydraulic habitat, altered carbon availability and removal of woody debris that supports biofilms, increased armouring and infilling of riffle and gravel habitats and the lack of emergent macrophytes in reaches two and three (Cottingham et al., 2014b).

Geomorphology

<u>Mid Goulburn</u>

The Index of Stream condition data obtained in 2013 on the physical form of the mid Goulburn River suggests the geomorphic condition of the river is generally moderate, which is an improvement since the 2004 assessment (Cottingham et al., 2014a). Moderate condition means the banks are relatively stable, wood is present but loads are not high, and barriers are not considered significant impediments to the movement of materials (sediment and carbon) and biota (Cottingham et al., 2014a). There is little evidence of large-scale channel changes (erosion and deposition) in recent years and banks are generally well vegetated with some patchiness in reaches 2 and 3. River surveys conducted as part of the 2014 flows study compared cross sections with those taken 12 years earlier and showed little evidence of large scale channel change over this time.

Lake Eildon acts as a large sediment trap, starving the river directly below the dam of sediments. Sediment supply downstream of Lake Eildon is very restricted due to the presence of the dam, and consequently the mid Goulburn River relies on tributaries for sediment input. Tributary inflows from the Acheron River, Yea River, King Parrot Creek and Sunday Creek replenish sediments back into the mid Goulburn. However some of these inflows can cause high turbidity and exacerbate substrate sediment smothering, which decreases habitat suitability for biota such as macroinvertebrates. Maintenance of bed diversity and channel form is essential for the health of the mid Goulburn River.

The reduced frequency of large flood events in the mid Goulburn have caused bed sediments to become armoured and therefore reduced substrate condition for macroinvertebrates and fish as interstices become clogged.

Lower Goulburn

The Index of Stream Condition physical form condition data obtained in 2013 of the lower Goulburn River rated the river in moderate condition; with the exception of the reach including Goulburn Weir which was ranked poorly due to a major barrier, low levels of instream woody debris and unstable banks. Overall, the lower Goulburn physical form condition has improved in ISC rating at all reaches since 2004.

Cottingham et al. (2007) describe the geomorphology of the lower Goulburn River in detail. Reach four is characterised by three distinct features; sandy point bars, point bars, point benches and concave benches. Reach five has developed more recently with channel avulsions downstream of Loch Garry causing the river to migrate south and consequently has had limited lateral migration with no well-developed concave benches or point bars.

Lake Eildon and Goulburn Weir effectively act as sediment traps for all course sediments entering the river and consequently the lower Goulburn is starved of coarse sediment loads. In the lower Goulburn, the only sources of incoming sediments are from bank erosion and tributaries (e.g. Sevens Creek, Broken River). The granite hills tributaries (i.e. Pranjip, Castle and Sevens Creeks) have large sand loads, however this sediment is caught in sand slugs moving very slowly though each system and have not yet reached the Goulburn River.

The river banks of the Goulburn River are naturally actively eroding and can contribute some sediment load to the river. However, bank erosion became an issue in the lower reaches of the river after the delivery of environmental freshes in 2012-2013. Bank slumping was observed in the lower sections of Reach five and is thought to be from a range of issues such as too rapid drawdown of flows, angel of the river bank, bank notching leading to steep banks and loss of toe support. Notching during the fresh delivery in 2013-2014 was significantly less than in the previous year with occasional lower bank erosion issues reported since 2014.

Water Quality

The water quality in the mid Goulburn River is considered to be generally good, with the main issue being cold water pollution from Lake Eildon releases (Cottingham et al., 2014a). High nutrient concentrations and low levels of dissolved oxygen have historically been water quality issues in the lower Goulburn River, however changes to irrigation and farm practices have reduced nutrient loads.

5.2 Condition Trajectory

5.2.1 Do nothing…..

The delivery of environmental water to the Goulburn River has only been occurring for approximately four years. There have been significant gains and recovery of some aspects of the riverine environment since this time, including successful Golden perch breeding for the first time in more than ten years, and recovery of bank and instream vegetation in the lower Goulburn River. Without environmental water these outcomes are unlikely to have been achieved.

Without further environmental watering, the Goulburn River would not improve in health as it appears to be doing at present. Flow dependant fish and flora species would decline in health, abundance and diversity. Native fish spawning and recruitment would rely solely on natural fluctuations for spawning, and subsequent flows to nurture juveniles in slack water habitats. Delivery of environmental water can specifically target these flow types to ensure the continued improvement of our native fish populations. Currently overbank flows cannot be delivered along the mid and lower Goulburn River. Investigations into opportunities to deliver overbank flows are currently being conducted. Floodplain vegetation and ecosystems would decline in health as large overbank floods do not occur as frequently as in the past, and floodplain levees reduce the ability of flood flows to reach the floodplain. Upper bank and floodplain vegetation will not get water required for seed dispersal and regeneration.

All recommendations in the flow plans developed for the mid and lower Goulburn River would not be met, and consequently their targeted objectives would not be achieved.

Delivery of irrigation water under a ‘do nothing’ scenario would continue in a manner most efficient and timely for the end user, rather than taking into consideration implications on the river environment and ecology. This may lead to increased bank erosion and reduced water quality.

5.2.2 Basin Plan

The implementation of the Murray-Darling Basin Plan will provide a high level framework that sets standards for the Australian Government, Basin States and the Murray-Darling Basin Authority to manage the Murray-Darling Basin’s water resources in a coordinated and sustainable way. The implementation of this plan provides hope for the continued increase in health of the Goulburn River.

The provision of all flow components (baseflow, freshes and overbank flows) will have a positive impact on the ecology such as native fish populations and recruitment, floodplain vegetation regeneration and the contribution of organic matter to the river for stream metabolism.

5.3 Water Related Threats

The following are a selection of flow related threats specific to various river health values listed below. Cottingham et al (2014), reported on these issues in the Mid Goulburn River Environmental Flows Study: Issues paper. A majority of these relate to the lower Goulburn River also.

Geomorphology

- Reduced frequency of flow events capable to provide diverse bed morphology.
- Reduced frequency of flow events that maintain connectivity with the floodplain.
- Rates of drawdown in river level are too rapid and result in bank slumping.
- Constant rates of flow height causing bank notching.

Water Quality

- Warm water floods leading to low dissolved oxygen issues.
- Cold water releases from Lake Eildon (mid Goulburn River).
- Sediment and nutrient inputs from catchment run off.

Riverine vegetation

- Decreased flow variability restricting the ability of zone appropriate vegetation establishing on the river banks.
- Decreased incidence of overbank flows.
- Unfenced riparian zones causing vegetation degradation and removal.

Invertebrates

- Reduced frequency of flow events capable of scouring sediments from pools.
- Longer than natural duration of low flow events leading to excess deposition of fine materials.
- High summer flows that reduce riverine productivity at most trophic scales.
- Reduced duration of fresh flows potentially interrupting carbon and nutrient cycling and inputs.

Fish

- Unseasonal flow regime that reduces habitat availability and connectivity.
- Unseasonal flow regime results in lack of spawning cues for native fish.
- Cold water pollution (mid Goulburn River).

The river banks of the Goulburn River are naturally actively eroding. However, notching has become an issue in the lower reaches of the River after the delivery of freshes in 2012-2013. Notching during the 2013-2014 freshes was significantly reduced from levels seen in 2012-2013, due to slower rates of falls from fresh flows, and managing water levels so they are not held at a consistent height for an extended period. Odd lower bank erosion issues have also been reported in 2014-2015, but their relationship to environmental releases is still to be clarified. Monitoring of erosion occurrences and rates is occurring on the banks of the Goulburn River between Toolamba and Yambuna as part of a five year monitoring program (refer to Section 9.1-Monitoring priorities at the site).

6. Management Objectives

6.1 Management Goal

The following long term management goal for the Goulburn River has been informed by a variety of technical studies, the Goulburn Broken Waterway Strategy, advice from scientific experts and the environmental values it supports. The Goulburn River long term management goal is:

Protect and improve the Goulburn River's important aquatic flora and fauna, instream habitats, connected floodplains and ecological processes.

6.2 Ecological Objectives

The overarching ecological objectives in Table 7 describe the desired ecological outcomes of the site to be achieved through the provision of environmental water and flow management over the next ten years. They encompass the more detailed ecological objectives established for the site by various flow studies and technical reports as described in section 6.3 below.

Table 7: Ecological objectives for the Goulburn River

Ecological Value	Long-term overarching ecological objectives	Target ecological objective mid Goulburn	Target ecological objective lower Goulburn	Rationale
Native Fish	1. Increase the abundance, spatial distribution and size class diversity of key native fish species.	Macquarie Perch	Murray Cod, Golden Perch and Silver Perch	Native fish contribute to aquatic biodiversity, are a key predator in aquatic food webs and are valued for recreational fishing.
Native Vegetation	2. Increase the abundance and richness of aquatic and flood dependent native species.	Instream	Instream and lower bank	Aquatic and flood dependent vegetation support aquatic ecosystems. They supply energy to support food webs, provide habitat and dispersal corridors for fauna, reduce erosion rates and enhance water quality.
Macroinvertebrates	3. Increase macroinvertebrate biomass and diversity.	Shrimp, yabbies, dragonflies and damselflies	All macroinvertebrates	Macroinvertebrates are an important food source for aquatic fauna including native fish (threatened and recreational species). Functional feeding groups assist with different ecological functions of the river.
Geomorphology	4. Protect and promote natural channel form and dynamics (e.g. sediment diversity, rates of sediment transport and bank erosion rates) 5. Increase instream physical habitat diversity (e.g. shallow and deep water habitats).	Interstitial spaces and channel benches	Natural sediment movement and pools	Geomorphic process contribute to the availability and quality of physical instream habitat diversity.
Stream Metabolism*	6. Provide sufficient rates of in-stream primary production and respiration to support native fish and macroinvertebrate communities.	NA	NA	Stream metabolism provides the energy base that underpins aquatic food webs.

Note: There are currently no target ecological objectives for Stream Metabolism in the mid and lower Goulburn. These objectives are covered by the other objectives listed in this table. It is hoped target ecological objectives for stream metabolism will be developed following the completion of the Long Term Intervention Monitoring Program, which is monitoring and evaluating the ecological effects of Commonwealth environmental water on stream metabolism.

6.3 Flow Recommendations

A series of flow-related ecological objectives and associated flow recommendations have been developed for the Goulburn River in a number of environmental flows and technical studies. Details of each study can be found in Appendix 4. Table 8 and Table 9 list selected flow recommendations from these studies. These recommendations have been extracted as a sub set of priorities to target in the next ten years. However, additional ecological objectives and flow recommendations may be targeted if the opportunity or need arises. The selected recommendations have been separated into mid Goulburn and lower Goulburn. Where a certain flow component (e.g. baseflow) has a range of flow recommendations, these have been combined for ease of reading into one component with a range of flows. The range of flows for each component therefore corresponds to different requirements for specific reaches and/or objectives.

The priority of delivering these flow recommendations can change annually depending on the ecological condition of the river and water availability. All the flow recommendations in Table 8 and Table 9 have various tolerances depending on specifics of the reach and climatic conditions (e.g. baseflow geomorphic objectives vary depending on which process you wish to target). The range of tolerances are too numerous to detail in this report and can be found in the specified report as listed in the tables.

The feasibility of delivering the overbank and bankfull flow recommendations, including how best to deliver or supplement unregulated flows, whilst avoiding damage to public and private assets is an issue requiring further investigation. Therefore overbank and bankfull flow recommendations are only met by natural events.

In reach one (Lake Eildon to the Yea River), trout fishing produces substantial economic and social benefits. In Cottingham et al. (2014b) a number following flow recommendation were identified to benefit trout which are outlined in Appendix 5.

Table 8: Environmental Objectives and Flow recommendations for the mid Goulburn River

Reach	Flow Component	Flow (ML/DAY)	Duration	Season	Ecological Value	Overarching Ecological Objectives	Ecological Objectives	Report
1 - 3	Baseflow	400 – 800 or natural	All year	All	• Macroinvertebrate • Native vegetation • Native fish	• 1 • 2 • 3	• Maintain riffles for macroinvertebrates and small bodied fish, maintain wetted perimeter and aquatic vegetation	2014
1	Fresh	900	1 day	Winter/ Spring	• Geomorphology • Macroinvertebrate	• 3 • 4 • 5	• Scour fine sediments from riffle surfaces to maintain macroinvertebrate habitat	2014
1 - 3	Fresh	2500 – 3500	5-7 days 2 per year	All	• Macroinvertebrates • Native fish	• 1 • 3	• Increase flow variability to more closely mimic natural hydrological regime to maintain riffle habitats	2014
2 - 3	Fresh	0.5m increase in stage height over one week	7 days	Spring	• Native fish	• 1	• Provide flows to promote large bodied endangered species colonisation • Promote Macquarie perch spawning	2014
1	Bankfull*	7000-9000	2 days	Winter/Spring	• Geomorphology	• 4 • 5	• Maintain channel form and key habitats (including in channel benches)	2014
1 - 3	Bankfull*	11000 – 13000	Reach 1 and 2 (1-4 days) Reach 3 (2 days)	Winter/Spring	• Geomorphology • Native Fish • Native vegetation • Macroinvertebrate	• 1 • 2 • 3 • 4 • 5	• Maintain bed diversity and channel form • Provide flows to increase native fish recruitment and colonisation • Provide periodic regeneration opportunities for native riparian species • Retain natural seasonality for macroinvertebrate life stages • Maintain or increase connection to warmer water	2014
3	Bankfull*	14000	1-4 days	Spring and Autumn	• Geomorphology • Native fish • Native vegetation	• 1 • 2 • 4 • 5 • 6	• Maintain bed diversity • Provide opportunities for regeneration of riparian and floodplain flora and fauna species and improve in channel carbon availability • Retain natural seasonality to ensure synchronicity of life cycle of macroinvertebrates	2014
1 – 3	Overbank*	15000 – 20000	1-4 days	Winter Spring	• Geomorphology • Native fish • Native vegetation • Macroinvertebrate	• 1 • 2 • 3 • 4	• Maintain channel form • Provide floodplain connection for exchange of organic matter • Provide periodic regeneration opportunities for native floodplain riparian and wetland plants	2014

Reach	Flow Component	Flow (ML/DAY)	Duration	Season	Ecological Value	Overarching Ecological Objectives	Ecological Objectives	Report
						• 5 • 6	• Provide lateral connectivity as habitat and recruitment areas for native fish	
1	Rate of flow rise	Max rate 2.0 (i.e. 2 times previous days flow) for flows from 1000-5000 ML/day. 2.7 times previous days flow for flows above 5000 ML/day		All year	• Native fish • Macroinvertebrate	• 1 • 3	• Reduce displacement of macroinvertebrates and small/juvenile fish	2014
1	Rate of flow fall	Max rate 0.8 of previous days flow		All year	• Geomorphology • Native fish • Macroinvertebrates	• 1 • 3 • 4 • 5	• Reduce bank slumping/erosion and stranding of macroinvertebrates and small/juvenile fish	2014

*Proposed flows only, cannot currently deliver

Table 9: Environmental Objectives and Flow recommendations for the lower Goulburn River

Reach	Flow Component	Flow (ML/DAY)	Duration	Season	Ecological Value	Overarching Ecological Objectives	Ecological Objectives	Report
4 - 5	Baseflow	320 - 540	All year	All	• Native fish	• 1	• Provide suitable in channel habitat for all life stages.	2007
4 – 5	Baseflow	830 - 940	All year	All	• Macroinvertebrate	• 3 • 6	• Provide habitat and food source for macroinvertebrates by submerging snag habitat within the euphotic zone • Entrain litter packs available as food/habitat source for macroinvertebrate • Maintain water quality suitable for macroinvertebrate	2007
4 – 5	Baseflow/fresh	Ranging from 856 – 6,060	< 90 days	Summer	• Geomorphology	• 4 • 5	• Maintain pool depth and natural rates of sediment deposition	2007
4 – 5	Fresh	5600	2-4 days 1-4 events a year	Spring Summer	• Native fish	• 1 • 2 • 3	• Initiate spawning of Golden Perch, migrations of Murray Cod and Silver Perch and recruitment of other native fish (preferably late spring /early summer) • Maintain aquatic macrophyte, macroinvertebrate and fish habitat by mobilising fine sediments, submerging snags and replenishing slackwater habitat	2010
4 – 5	Fresh	5600	2-4 days 1-4 events a year	Summer Autumn	• Native vegetation	• 2 • 3	• Establish amphibious and lower bank vegetation • Maintain aquatic macrophyte, macroinvertebrate and fish habitat by mobilising fine sediments, submerging snags and replenishing slackwater habitat	2010
4 – 5	Fresh	5600	14 days 1-4 events a year	Winter Spring	• Native vegetation	• 2	• Remove terrestrial vegetation and re-establish amphibious and lower bank vegetation	2010
4	Overbank*	25 000	5+ days 2-3 events in a year 7-10 event years in 10	Winter Spring	• Native vegetation	• 2 • 6	• Increase the extent and diversity of flood dependent vegetation communities • Provide habitat for wetland specialist fish • Exchange of food and organic material between the floodplain and channel • Increase breeding and feeding opportunities for native fish, waterbirds and amphibians	2011
4	Overbank*	40 000	4+ day 1 – 2 events in a year 4 - 6 event years in 10	Winter Spring	• Native vegetation	• 2 • 6	• Increase the extent and diversity of flood dependent vegetation communities higher on the floodplain • Provide habitat for wetland specialist fish • Exchange of food and organic material between the floodplain and channel	2011

Reach	Flow Component	Flow (ML/DAY)	Duration	Season	Ecological Value	Overarching Ecological Objectives	Ecological Objectives	Report
							• Increase breeding and feeding opportunities for native fish, waterbirds and amphibians	
4	Rate of flow rise	Max rate of 0.38/0.38/1.20/0.80 metres river height in summer/autumn/ winter/spring		All year	• Native fish • Macroinvertebrate	• 1 • 3	• Reduce displacement of macroinvertebrates and small/juvenile fish	2007
4	Rate of flow fall	Max rate of 0.15/0.15/0.78/0.72 metres river height in summer/autumn/ winter/spring		All year	• Geomorphology • Native fish • Macroinvertebrate	• 1 • 3 • 4 • 5	• Reduce bank slumping/erosion and stranding of macroinvertebrates and small/juvenile fish	2007

*Proposed flows only, cannot currently deliver

7. Managing Risks to Achieving Objectives

Cottingham et al. (2011) outlined the risks of environmental water delivery in the lower Goulburn River. These risks are also applicable to the mid Goulburn and Table 10 has been extracted from this document (GBCMA, 2007). The risk assessment in Table 10 provides an indication of the risks associated with the delivery of environmental water in the Goulburn River. It should be noted that risks are not static and require continual assessment to be appropriately managed. Changes in conditions will affect the type of risks, the severity of their impacts and the mitigation strategies that are appropriate for use. As such, a risk assessment must be undertaken prior to the commencement of water delivery. A framework for assessing risks has been developed by Department of Sustainability, Environment, Water, Populations and Communities (SEWPAC) and is included at Appendix 6 (GBCMA, 2007).

Table 10: Risks associated with water delivery in the mid and lower Goulburn River

Risk type	Description	Likelihood	Consequence	Risk level With control in place	Mitigation Strategies
Salinity	Releases from Lake Eildon and Goulburn Weir to the lower Goulburn River are of good quality and do not pose salinity risks at the volumes proposed.	Unlikely	Minor	Low	Salinity is monitored and the Goulburn water quality reserve could be called upon to reduce (dilute) saline water, if this was necessary (unlikely).
Invasive species	Carp breeding can occur, along with that of native fish. Invasive aquatic macrophytes (e.g. *Sagittaria*) occur across the region.	Likely	Moderate	Medium	Carp - none practicable. Invasive aquatic macrophytes – continued surveillance and eradication or control.
Low DO (e.g. from blackwater events)	Fish kills have occurred in the Goulburn River, with low DO being implicated although the exact cause of these deaths was difficult to determine (e.g. Koehn 2004, Sinclair 2004). Low DO events after the Black-Saturday bushfires have been attributed to catchment runoff from bushfire-affected tributaries. A blackwater event and fish kill has recently (December 2010) occurred with floodplain inundation during the second of two floods in spring 2010.	Possible, depending on antecedent conditions.	Major	High	Continue the GB CMA monitoring of low DO incidents. Most environmental flows proposed will not leave the river channel, reducing the risk of low DO and blackwater that might occur with flooding. The risk of low DO with flooding could also be reduced by limiting controlled overbank flows to winter-spring.
Water loss	There is high uncertainty regarding magnitude of losses downstream of Lake Eildon, particularly at high flow rates. Modelling suggests that in the order of 100 GL can be retained on the floodplain in overbank events (G. Earl, GB CMA, pers. comm. 2011).	Likely	Minor	Medium	Review losses along Goulburn River. Allow for losses, if necessary, when estimating allocations.
Estimation of water availability and volumes required	Volumes associated with water delivery options depend on modelling. Modelling accuracy may result in an underestimation of the actual volumes actually required increasing the likelihood of shortfalls of water required to achieve objectives.	Possible	Moderate	Medium	Confirmation that volume(s) released achieve the desired hydrological and ecosystem outcomes and adjustment of volumes as required (within flow constraints – see flooding risks below).
Cold water releases from Lake Eildon affecting the Lower Goulburn.	The release of colder bottom waters from Lake Eildon mainly affects water temperature between Lake Eildon and Seymour. It is not expected to affect water temperature below Goulburn Weir.	Unlikely	Minor	Low	

Risk type	Description	Likelihood	Consequence	Risk level With control in place	Mitigation Strategies
Flooding	Risk of flooding sites along the river, commencing at 14 500 ML/day downstream of Lake Eildon.	Unlikely	Moderate	Low	Flows resulting from environmental water releases will be actively managed by river operators to remain below minor flood levels (14 500 ML/day immediately downstream of Lake Eildon).
	Excessive erosion and bank instability.	Unlikely	Moderate	Low	Appropriate rates of rise and fall at Lake Eildon and Goulburn Weir avoid excessive bank erosion. Use the findings of the Long term intervention monitoring bank condition monitoring to inform rates of rise and fall.
	Loss of public amenity and risk to recreational users of the river.	Possible	Minor	Low	Notification of potential loss of public amenity and potential hazards with delivery of flow events.
	Inability to achieve environmental objectives for overbank events due to flow constraints.	Likely	Moderate	Medium	Overbank flow objectives are not currently feasible due to delivery constraints.

The key risk management activities with immediate outcomes include:

- management of flooding risk associated with delivering freshes by considering potential rainfall runoff in deciding when to commence releases and whether to cease releases prematurely; and
- to keep key stakeholders advised of release plans and outcomes of releases.

Importantly risks associated with our current level of knowledge need attention now, but will take time to reduce the associated risks.

The risk of flooding arises from catchment runoff adding flow on top of environmental releases. The key issue is the unpredictability of the amount of rainfall and runoff. At Shepparton, flooding occurs at approximately 18 000 ML/day, although inundation of some individual assets (such as irrigation pumps) occurs at much lower flows. Managing the risk of flooding is a balance in determining spare capacity in the river to carry the rainfall runoff and the potential reduction/suspension of environmental releases required when rainfall is forecast. The highest flow (due to capacity constraints) from Lake Eildon that can be provided is 9000 to 10 000 ML/day under dry conditions, and assumes no irrigation water supply demand. This leaves 8000 to 9000 ML/day of spare river capacity in the lower Goulburn to carry runoff on a dry catchment. Under wet conditions, lower flow releases would be needed to deal with the potentially higher runoff downstream of Lake Eildon. The higher the flow rate (due to runoff), the more likely the flow release would be reduced or ceased due to the uncertain response to rain, making provision of the environmental or water supply flow erratic and potentially unreliable.

Other water delivery

While this Environmental Water Management Plan focuses on how to use water to maximize environmental benefits to the Goulburn River, water supply and environmental releases can be routed through the Goulburn River to the Murray River for other purposes. For example, The Living Murray water targets environmental outcomes at the six Murray icon sites, and Inter-Valley Transfers are targeted at meeting consumptive water demand in the Murray River. Some of these releases can pose a risk to the Goulburn River and may increase the risk of flooding private and public infrastructure which needs to be managed.

In the lower Goulburn River, water releases in winter/spring generally pose little risk to the environment provided flow rates of rise and fall are not greater than those specified in Cottingham et al. (2007). Cottingham et al. (2007) recommended the following maximum rates of river level rise and fall for each four (Table 11).

Table 11: Maximum rates of river level rise and fall for reach 4

	Winter	Spring
Rise (metres/day)	1.2	0.80
Fall (metres/day)	0.78	0.71

Experience in 2012-2013 indicates that slower rates of fall are preferable, particularly after prolonged flows. These are currently determined on a case by case basis.

For water releases in summer and autumn, Cottingham et al. (2007) identified significant environmental risk from persistent high flows. Key impacts include:

- Bank notching and erosion.
- Bank slumping.
- Filling of pools.
- Loss of macrophytes.
- Reduced phytoplankton production.
- Reduced macroinvertebrate growth.

Essentially this limits the maximum flow to 5240 ML/day at McCoys Bridge for a maximum of two days over this period in a median climatic year to pose a low risk to the environment. Greater durations are allowable for lower flow rates. As a guide, flows greater than approximately 2500 ML/day can occur for less than 50 per cent of the time (determined by season). Rates of rise and fall also pose a risk, and Cottingham et al. (2007) recommended maximum rates of rise in reach four of 0.38 metres/day for summer and autumn, and maximum rates of fall of 0.09 metres/day for both summer and autumn, with rates desirably less than these.

In the mid Goulburn River, water releases in winter/spring generally pose little risk to the environment provided rates of rise and fall are not greater than those specified in Cottingham et al. (2014a). For reach one, Cottingham et al (2014b) recommended the maximum rate of rise be limited to 2.0 times the previous days flow (for flows from 1000 to 5000 ML/day) and 2.7 times the previous days flow (for flows above 5000 ML/day). Maximum rates of fall should be limited to 0.8 times the previous days flow. These rates of rise and fall are applicable throughout the year in this reach.

In the mid Goulburn River, water releases in summer/autumn (and some springs) are consistently too high as water is transferred from Lake Eildon to Goulburn Weir to meet irrigation demands. Cottingham et al. (2003) identified the need for flows to be between 1400 to 3000 ML/day in order to provide shallow water habitat suitable for macrophytes and fish recruitment; they also recognised although ecologically desirable, these were not consistent with social and economic imperatives.

8. Environmental Water Delivery Constraints

Cottingham et al. (2003) considered the following were constraints on achieving environmental flow recommendations:

- The capacity to release large volumes of water from Lake Eildon and the potential for minor flooding, with potential bed and bank erosion and damage to infrastructure as assets.
- The potential that ecological outcomes expected with additional releases may be negated if the water temperature is too cold.
- Lack of flexibility in operations due to level of commitments and extensive rules for operating Lake Eildon and associated hydroelectricity power generation.
- High demands for Goulburn water outside the catchment and potential future demands (e.g. providing more water for the Murray River).
- Balancing the differences in the volumes required to inundate floodplain areas in middle reaches with that of downstream reaches.
- Land management practices.
- The maintenance of Goulburn Weir as an important recreational and social amenity.

Achieving overbank flows and connecting the river with its floodplain is important for river health. The achievement of overbank flows is difficult in both the mid and lower Goulburn, for differing reasons. The report '*Assessment of environmental water requirements for the proposed Basin Plan: Lower Goulburn River Floodplain*' discusses the flow delivery constraints for the lower Goulburn River (GBCMA, 2010). This information below has been extracted from this document.

Goulburn-Murray Water generally operates Lake Eildon so that flows along the mid Goulburn River in reach one do not exceed approximately 9500 ML/day in order to avoid inundation of private land, and public and private infrastructure. This limitation, combined with an obligation to avoid overbank flows when delivering environmental water, constrains environmental releases to the river channel and means that the river channel is not connected to its floodplain.

Flows downstream of Lake Eildon are typically limited to 12 000 ML/day or 18 000 ML/day under regulated conditions at Seymour and Trawool respectively to avoid flooding of private land around these areas. In addition, delivery constraints also exist in the lower sections of the Goulburn River around Shepparton and areas further downstream to avoid flooding of private land and minor roads not protected by existing levees. These constraints will at times, prevent the release of flows or adding water to augment natural flows to achieve flow indicators specified for the lower Goulburn River floodplain (GBCMA, 2010).

Achievement of a 25 000 ML/day and 40 000 ML/day site specific flow indicators at Shepparton will be difficult with only regulated releases from dams. Achieving these higher flows will be possible only by supplementing tributary inflows: even this may not provide the required flows as there is no guarantee of achieving the required duration, as this will be determined by the duration of the tributary inflow.

According to the Victorian Department of Sustainability and Environment (2011) flows up to 40 000 ML/day at Shepparton are achievable within existing physical constraints and it is possible to avoid major risks and liabilities that would be associated with managed environmental flow releases that exceeded this flow rate (e.g. flooding of private rural and urban land, damage to the existing levees, impacts on water resource reliability and the ability to deliver an event).

This was confirmed by hydrological modelling undertaken by the MDBA to inform the proposed draft Basin Plan (GBCMA, 2010). However, in some years flood constraints downstream of Lake Eildon may limit the ability to augment tributary inflows and hence impede the ability to achieve the flow indicators (specifically the maximum period between events).

Overcoming constrains to watering the floodplain (and associated wetlands) is an issue currently being considered under the Murray-Darling Basin Plan. In the case of the mid Goulburn River, this means exploring how best to overcome constraints in environmental water delivery from the current upper limit of 9500 ML/day up to 20 000 ML/day. The delivery of overbank flows will not occur until constraints such as inundation of private land and public and private infrastructure, effects of block banks and levees have been addressed (Cottingham et al., 2014a). In the lower Goulburn, this means exploring how best to overcome constraints in environmental water delivery from the current limit of 8,000-15,000ML/d up to 18,000ML/d (Earl, 2015).

9. Consultation

The recently completed Goulburn Broken Waterway strategy (2014-2022) was developed in consultation with a steering committee comprising community and agency representatives. The goals of the waterway strategy underpin the relevant management and ecological objectives identified in the Goulburn River Environmental Water Management Plan.

The Goulburn Broken CMA has utilised information from steering committees developed to inform the Goulburn River flows studies to assist with the development of this plan. These steering committees (Cottingham et al., 2014a, Cottingham et al., 2003, GBCMA, 2007, GBCMA, 2014b) provided input to the differing flow studies reports for the Goulburn River which is the basis of both ecological and hydrological objectives for this report. These steering committees were made up of community members, agency staff and technical experts.

The Goulburn River Environmental Water Advisory Group is currently in the process of review and did not meet during the development of this plan. They are expected to reconvene in 2015-2016 and will be engaged on the plans implementation and future refinements.

10. Demonstrating Outcomes

10.1 Monitoring Priorities at the site

River flows and water quality are currently monitored through the North East Monitoring Partnership. Continuous flow is monitored along the Goulburn River at Lake Eildon, Trawool, Seymour, Murchison, Shepparton, Loch Garry and McCoys Bridge. The monitoring site at Loch Garry is temporary as it has been installed to measure flow as part of a Long Term Intervention Monitoring project (refer below). Following completion of this program the need to continue to monitor this site will be assessed. GMW also monitors Goulburn Weir releases.

Water quality monitoring includes continuous (i.e. 15 minute intervals) and non-continuous monitoring. Continuous monitoring started in 2009 (primarily in response to drought) and non-continuous monitoring started more than ten years. Table 12 lists the sites, frequency and parameters that are used for environmental flow monitoring. This monitoring is used frequently (sometimes daily) in short term environmental flow management to assist decision making, especially for minimising the risk of dissolved oxygen sags and potential fish kills or other water quality issues.

Table 12: Water quality monitoring sites on the Goulburn River used in environmental flow management

Site	Parameter
Continuous monitoring	
Mid Goulburn	
Goulburn River@Trawool	Turbidity, electrical conductivity, temperature, level
Goulburn River@Seymour	Continuous flow monitoring only
Goulburn River@Tahbilk	Dissolved oxygen, temperature, electrical conductivity
Goulburn River@Goulburn Weir	Dissolved oxygen, temperature, turbidity
Lower Goulburn	
Goulburn River@Murchison	Temperature, electrical conductivity
Goulburn River@Shepparton Golf Club	Dissolved oxygen, temperature
Goulburn River@McCoys Bridge	Dissolved oxygen, electrical conductivity, temperature, level
Non continuous monitoring	
Mid Goulburn	
Goulburn River@Eildon	Dissolved oxygen, temperature, turbidity, electrical conductivity, suspended solids, TP, TN
Goulburn River@Trawool	Dissolved oxygen, temperature, turbidity, electrical conductivity, suspended solids, TP, TN
Lower Goulburn	
Goulburn River@Murchison	Dissolved oxygen, temperature, turbidity, electrical conductivity, suspended solids, TP, TN
Goulburn River@Shepparton	Suspended solids, turbidity, TP, TN
Goulburn River@Loch Garry	Flow monitoring as part of the Commonwealth Long Term Intervention Monitoring program
Goulburn River@McCoys Bridge	TP, TN, dissolved organic carbon

Four monitoring programs in the Goulburn Broken catchment aim to specifically monitor environmental flows and associated ecological responses. The longest running program is the Victorian Environmental Flows Monitoring and Assessment Program (VEFMAP). This program commenced in 2008-2009 at twelve sites in the lower Goulburn River. It involves monitoring vegetation, fish, macroinvertebrates, channel features and physical habitat: not all parameters are measured at each site. The assessments are carried out on a range of timeframes (varying from annual, to when a channel changing event occurs) and are a long term assessment (five to ten years) of the impacts and changes from environmental flows. Data are analysed using Bayesian Hierachical statistics rather than a before-after style approach. 2010-2011 was the first year to have significant flows and hence the first year that any flow response may occur. Consequently, the previous year's monitoring provided baseline data only. Since 2011-2012, environmental water has been released every year and VEFMAP monitoring may be able to detect some response. The future of VEFMAP is currently being reviewed for methods, data analysis and funding.

Following two years of short term intervention monitoring (2012-2014), the Commonwealth Environmental Water Holder commenced a long term (five year) environmental monitoring program in the lower Goulburn River – the Long Term Intervention Monitoring (LTIM) program (GMW, 2014). The program commenced in 2014-2015 and is monitoring fish populations, fish spawning and movement, stream metabolism, macroinvertebrate diversity and biomass, vegetation diversity, hydrology and hydraulics, physical habitat and bank condition. Monitoring is focused on reach five of the Goulburn River (Loch Garry to the Murray River), with some additional monitoring in reach four (Goulburn Weir to Loch Garry).

11. Knowledge Gaps and Recommendations

Knowledge gaps associated with the environmental water management in the Goulburn River were identified in the Mid-Goulburn Flows study (GBCMA, 2011) and the (Cottingham et al., 2013) Goulburn River Seasonal Watering Proposal 2015-2016 (Cottingham et al., 2013). These are:

- How much reliance do juvenile native fish have on slack water habitats?
- How productive are slack water habitats?
- How does bank vegetation respond to flows with respect to bank slope and aspect?
- What are the best rates of rise and fall when delivering flows throughout different seasons of the year?
- Why is there low macroinvertebrate biomass in the mid Goulburn River compared to the lower Goulburn River?
- Is the low number of macroinvertebrate biomass constraining growth/ abundance/ recruitment of native fish in the mid Goulburn River?
- Is cold water pollution having an impact on the movement of Macquarie perch and other native fish species in the mid Goulburn River?
- Are baseflow recommendations accurate to meet the desired ecological outcomes in the mid Goulburn River?
- Do the proposed freshes deliver the extent of scouring they are aimed at in the mid Goulburn River
- Are there any works that can be done to remove barriers to floodplain wetlands (primarily in the mid Goulburn)?
- What has caused the sand banks/bars near Toolamba to move?

Specifically relating to the Goulburn River, some key knowledge gaps occur in both the mid and lower Goulburn River (Table 13). Further, there is insufficient knowledge/information available to assess whether a number of key ecological objectives are met by the recommended flows in reaches four and five. These are listed below in Table 14. Note: some of these may be addressed by the proposed CEWH long term environmental monitoring program.

Table 13: Knowledge gaps and recommendations for the mid and lower Goulburn River

Knowledge Gap	Recommendation	Reach	Potential funding stream	Agency responsible for implementation	Funding source
Baseflows may cause low DO event from deep water stratified sections in Lake Eildon	Investigate future low DO events	1-3	Monitoring or technical	GMW or GB CMA	DEWLP, VEWH or CEWH
Baseflow effect on macroinvertebrates	Investigate habitat provision for macroinvertebrates by submerging snag habitat within the euphotic zone. Investigate the provision of slack water habitat for macroinvertebrates. Investigate the effects of litter packs available as food/ habitat source.	4 and 5	Monitoring	GB CMA	DEWLP
Baseflow effect on native fish	Investigate the provision of slack water habitat favourable for native fish.	4 and 5	Monitoring	GBCMA	DEWLP
Baseflow effect on planktonic algae	Investigate the provision of slack water habitat favourable for planktonic production.	4 and 5	Monitoring	GBCMA	DEWLP
Freshes may cause scouring event along river.	Compare extent of scouring and magnitude of fresh	1-3	Monitoring	GMW or GB CMA	DEWLP, VEWH or CEWH
Bankfull and commence to flow may not reach wetlands or floodplain due to landscape changes which impede movement of water across the floodplain	Assess possible impediments to wetlands and areas of high value along the floodplain and design an amelioration project if necessary	1-5	Technical and works and measures	GMW or GB CMA	DEWLP, VEWH or CEWH
Bankfull flows that reach wetlands may encourage alien fish species to breed	Investigate the possibility of carp exclusion screens or wetting and drying wetlands to reduce carp population numbers.	1-5	Works	GMW and/or GB CMA	DEWLP, VEWH or CEWH

Table 14: Ecological objectives not assessed

	Ecological values	Ecological objectives	Flow (ML/Day)

Flow component			Reach 4	Reach 5
Baseflow	Macroinvertebrates Native fish Planktonic algae	• Provide habitat and food source for macroinvertebrates by submerging snag habitat within the euphotic zone • Provide slackwater habitat favourable for planktonic production (food source), habitat for macroinvertebrates and juvenile fish • Entrain litter packs available as food/habitat source for macroinvertebrates • Maintain water quality suitable for macroinvertebrates	830	940
Fresh	Native fish Macrophytes Macroinvertebrates	• Maintain aquatic macrophyte, macroinvertebrate and fish habitat by mobilising fine sediments, submerging snags and replenishing slackwater habitat	5600+	5600+

12. References

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13. Appendices

Appendix 1 Listed species in the Goulburn River

Data extracted from Assessment of environmental water requirements for the proposed *'Basin Plan: Lower Goulburn River Floodplain'* (GBCMA, 2010); *'Lower Goulburn Wetlands Flora and Fauna Surveys'* (Cook, 2012); *'Mid Goulburn Wetlands Flora and Fauna Surveys'* (Race and Connell, 2012).

Species	Recognised in international agreement(s) [1]	*Environment Protection and Biodiversity Conservation Act 1999* (Cwlth)	*Flora and Fauna Guarantee Act 1998* (VIC)
Australasian bittern (*Botaurus poiciloptilus*)[2, 3]		E	E
Australasian shoveler (*Anas rhynchotis*)[4]			V
Baillon's crake (*Porzana pusilla*)[2, 3]			V
Barking owl (*Ninox connivens*)[2, 3]			E
Barred galaxias (*Galaxias fuscus*)[2, 3]		E	CE
Brown toadlet (*Pseudophryne bibronii*)[4]			E
Brush-tailed phascogale (*Phascogale tapoatafa*)[2, 3]			V
Bush stone-curlew (*Burhinus grallarius*)[2, 3]			E
Diamond firetail (*Stagonopleura guttata*)[4]			NT
Eastern great egret (*Ardea modesta*)[2, 3]	J, C		V
Flat-headed galaxias (*Galaxias rostratus*)[4]			V
Freckled duck (*Stictonetta naevosa*)[4]			E
Freshwater catfish (*Tandanus tandanus*)[2, 3]			E
Glossy Ibis (*Plegadis falcinellus*)	C		
Grey-crown babbler (*Pomatostomus temporalis temporalis*)[2, 3]			E
Ground cuckoo-shrike (*Coracina maxima*)[2, 3]			V
Hardhead (*Aythya australis*)[4]			V
Intermediate egret (*Ardea intermedia*)[4]			CE
Lace goanna (*Varanus varius*)[4]			V
Latham's snipe (*Gallinago hardwickii*)[2, 3]	J,C,R		
Lewin's rail (*Lewinia pectoralis*)[2, 3]			V
Little bittern (*Ixobrychus dubius*)[2, 3]			E
Macquarie perch (*Macquaria australasica*)[2, 3]		E	E
Magpie goose (*Anseranas semipalmata*)[2, 3]			NT
Marsh Sandpiper (*Tringa stagnatilis*)	J,C,R		
Murray cod (*Maccullochella peelii peelii*)[2, 3]		V	E

Murray–Darling rainbowfish (*Melanotaenia fluviatilis*)[2, 3]			DD
Musk duck (*Biziura lobata*)[4]			V
Painted honeyeater (*Grantiella picta*)[2, 3]			V
Rainbow Bee-eater (*Merops ornatus*)	J		
Royal spoonbill (*Platalea regia*)[4]			V
Sharp-tailed Sandpiper (*Calidris acuminata*)	J,C,R		
Silver perch (*Bidyanus bidyanus*)[2, 3]		CE	CE
Southern bell or growling grass frog (*Litoria raniformis*)[4]		V	E
Squirrel glider (*Petaurus norfolcensis*)[2, 3]			E
Superb parrot (*Polytelis swainsonii*)[2, 3]		V	E
Swift parrot (*Lathamus discolor*)[2, 3]		E	E
Trout cod (*Maccullochella macquariensis*)[2, 3]		E	CE
Turquoise parrot (*Neophema pulchella*)[2, 3]			NT
Unspecked hardyhead (*Craterocephalus stercusmuscarum*)			DD
White-bellied sea eagle (*Haliaeetus leucogaster*)[2, 3]	C		V
Flora			
Grey billy-buttons (*Craspedia canens*)[4]			E
Jericho wire-grass (*Aristida jerichoensis* var. *subspinulifera*)[4]			E
River Swamp Wallaby-grass (*Amphibromus fluitans*)		V	
Small Scurf Pea (*Cullen parvum*)		E	L
Western water-starwort (*Callitriche cyclocarpa*)[4]			V

CE = critically endangered DD = data deficient E = endangered L = listed NT = near threatened V = vulnerable

1 Japan–Australia Migratory Bird Agreement, China–Australia Migratory Bird Agreement, or Republic of Korea – Australia Migratory Bird Agreement

2 Victorian Department of Primary Industries (2010)

3 Department of the Environment, Water, Heritage and the Arts (2009)

4 Department of Sustainability and Environment (2009)

Appendix 2 Ecological Vegetation Classes (EVCs)

Mid Goulburn (Taken from NV2005 EVC layer – Arc GIS)

EVC #	EVC Name	Bioregional conservation status		Targeted for watering	Flood dependent EVC group names
		Murray fans	Victorian Riverina		
Wetland EVCs					
932	Wet Verge Sedgeland	-	-	.	
168	Drainage Line Aggregate	Vulnerable	Endangered	Yes	Drainage Line Aggregate
1022	Drainage Line Aggregate/ Riverine Swamp Forest Mosaic	Vulnerable	Endangered	Yes	
334	Billabong Wetland Aggregate	Depleted	Vulnerable	Yes	Billabong Wetland Aggregate
172	Floodplain Wetland Aggregate	Depleted	Vulnerable	Yes	Floodplain Wetland Aggregate
804	Rushy Riverine Swamp	Depleted	Depleted	Yes	Rushy Riverine Swamp
1090	Tall Marsh/ Open Water Mosaic	Least Concern	Depleted	Yes	Tall Marsh/ Open Water Mosaic
1081	Spike-sedge Wetland/ Tall Marsh Mosaic	Vulnerable	Vulnerable	Yes	Spike-sedge Wetland/ Tall Marsh Mosaic
810	Floodway Pond Herbland	Depleted	Vulnerable	Yes	Floodway Pond Herbland
74	Wetland Formation	Endangered	Endangered	No – major extent is outside the maximum floodplain inundation area of 60000 ML/d	-
125	Plains Grassy Wetland	Endangered	Endangered	No – major extent is outside the maximum floodplain inundation area of 60000 ML/d	-
Floodplain EVCs					
295	Riverine Grassy Woodland	Vulnerable	Vulnerable	Yes	Riverine Grassy Woodland
871	Riverine Grassy Woodland/ Plains Woodland/ Gilgai Wetland Complex	Depleted	NA	Yes	
1040	Riverine Grassy Woodland/ Riverine Swampy Woodland Mosaic	Vulnerable	Endangered	Yes	
56	Floodplain Riparian Woodland	Depleted	Vulnerable	Yes	Floodplain Riparian Woodland
1035	Floodplain Riparian Woodland/ Sedgy Riverine Forest Mosaic	Depleted	Vulnerable	Yes	
816	Sedgy Riverine Forest	Depleted	Vulnerable	Yes	Sedgy Riverine Forest
815	Riverine Swampy Woodland	Vulnerable	Vulnerable	Yes	Riverine Swampy Woodland

1099	Riverine Swampy Woodland/ Plains Grassy Wetland Mosaic	Endangered	NA	Yes	Riverine Swampy Woodland
814	Riverine Swamp Forest	Depleted	Depleted	Yes	Riverine Swamp Forest
1068	Riverine Swamp Forest/ Sedgy Riverine Forest Mosaic	Depleted	Vulnerable	Yes	
68	Creekline Grassy Woodland	Endangered	Endangered	Yes	Creekline Grassy Woodland
106	Grassy Riverine Forest	Depleted	Depleted	No – major extent is outside the maximum floodplain inundation area of 60 000 ML/d	-
823	Lignum Swampy Woodland	Vulnerable	Vulnerable	No – major extent is outside the maximum floodplain inundation area of 60 000 ML/d	-
Terrestrial EVCs					
803	Plains Woodland	Endangered	Endangered	No – EVC is not flood dependent	-
103	Riverine Chenopod Woodland	Endangered	Endangered	No – EVC is not flood dependent	-
264	Sand Ridge Woodland	Endangered	Endangered	No – EVC is not flood dependent	-
55	Plains Grassy Woodland	Endangered	Endangered	No – EVC is not flood dependent	-
66	Low Rises Woodland	Endangered	Endangered	No – EVC is not flood dependent	-
985	Sandy Beach	Endangered	Endangered	No – EVC is not flood dependent	-
267	Plains Grassland/ Plains Grassy Woodland/ Gilgai Wetland Mosaic	Endangered	Endangered	No – EVC is not flood dependent	-
882	Shallow Sands Woodland	Vulnerable	Endangered	No – EVC is not flood dependent	-

Lower Goulburn (Taken from Cottingham et al., 2011)

EVC #	EVC Name	Bioregional conservation status		Targeted for watering	Flood dependent EVC group names
		Murray fans	Victorian Riverina		
Wetland EVCs					
992	Water body – fresh	NA	NA	No – no native vegetation recorded	-
168	Drainage Line Aggregate	Vulnerable	Endangered	Yes	Drainage Line Aggregate
1022	Drainage Line Aggregate/ Riverine Swamp Forest Mosaic	Vulnerable	Endangered	Yes	
334	Billabong Wetland Aggregate	Depleted	Vulnerable	Yes	Billabong Wetland Aggregate
172	Floodplain Wetland Aggregate	Depleted	Vulnerable	Yes	Floodplain Wetland Aggregate
804	Rushy Riverine Swamp	Depleted	Depleted	Yes	Rushy Riverine Swamp
1090	Tall Marsh/ Open Water Mosaic	Least Concern	Depleted	Yes	Tall Marsh/ Open Water Mosaic
1081	Spike-sedge Wetland/ Tall Marsh Mosaic	Vulnerable	Vulnerable	Yes	Spike-sedge Wetland/ Tall Marsh Mosaic
810	Floodway Pond Herbland	Depleted	Vulnerable	Yes	Floodway Pond Herbland
74	Wetland Formation	Endangered	Endangered	No – major extent is outside the maximum floodplain inundation area of 60000 ML/d	-
125	Plains Grassy Wetland	Endangered	Endangered	No – major extent is outside the maximum floodplain inundation area of 60000 ML/d	-
Floodplain EVCs					
295	Riverine Grassy Woodland	Vulnerable	Vulnerable	Yes	Riverine Grassy Woodland
871	Riverine Grassy Woodland/ Plains Woodland/ Gilgai Wetland Complex	Depleted	NA	Yes	
1040	Riverine Grassy Woodland/ Riverine Swampy Woodland Mosaic	Vulnerable	Endangered	Yes	
56	Floodplain Riparian Woodland	Depleted	Vulnerable	Yes	Floodplain Riparian Woodland
1035	Floodplain Riparian Woodland/ Sedgy Riverine Forest Mosaic	Depleted	Vulnerable	Yes	
816	Sedgy Riverine Forest	Depleted	Vulnerable	Yes	Sedgy Riverine Forest
815	Riverine Swampy Woodland	Vulnerable	Vulnerable	Yes	Riverine Swampy Woodland

1099	Riverine Swampy Woodland/ Plains Grassy Wetland Mosaic	Endangered	NA	Yes	Riverine Swampy Woodland
814	Riverine Swamp Forest	Depleted	Depleted	Yes	Riverine Swamp Forest
1068	Riverine Swamp Forest/ Sedgy Riverine Forest Mosaic	Depleted	Vulnerable	Yes	
68	Creekline Grassy Woodland	Endangered	Endangered	Yes	Creekline Grassy Woodland
106	Grassy Riverine Forest	Depleted	Depleted	No – major extent is outside the maximum floodplain inundation area of 60 000 ML/d	-
823	Lignum Swampy Woodland	Vulnerable	Vulnerable	No – major extent is outside the maximum floodplain inundation area of 60 000 ML/d	-
Terrestrial EVCs					
803	Plains Woodland	Endangered	Endangered	No – EVC is not flood dependent	-
103	Riverine Chenopod Woodland	Endangered	Endangered	No – EVC is not flood dependent	-
264	Sand Ridge Woodland	Endangered	Endangered	No – EVC is not flood dependent	-
55	Plains Grassy Woodland	Endangered	Endangered	No – EVC is not flood dependent	-
66	Low Rises Woodland	Endangered	Endangered	No – EVC is not flood dependent	-
985	Sandy Beach	Endangered	Endangered	No – EVC is not flood dependent	-
267	Plains Grassland/ Plains Grassy Woodland/ Gilgai Wetland Mosaic	Endangered	Endangered	No – EVC is not flood dependent	-
882	Shallow Sands Woodland	Vulnerable	Endangered	No – EVC is not flood dependent	-

Appendix 3 Criteria for identifying an ecosystem function related to the Goulburn River

Item	Criteria	Description
Criterion 1: The ecosystem function supports the creation and maintenance of vital habitats and populations		

1	Assessment indicator: An ecosystem function requires environmental watering to sustain it if it provides vital habitat, including: (a) a refugium for native water-dependent biota during dry periods and drought	During the millennium drought, deep pools were surveyed for dissolved oxygen stratification in the lower Goulburn River. Results indicated little to no stratification therefore providing good refuge for native fish (reach 4 and 5). The mid Goulburn River has irrigation flows occurring during 9 months of the year. These flows provide baseflow and refuge for native water dependent biota in the Goulburn and its tributaries (Reach 1-3).
	(b) pathways for the dispersal, migration and movement of native water-dependent biota	Reaches 4 and 5 are not impacted by any barriers and connect to the Murray River and combined with the Broken River provide 325 kilometres of waterway for passage of water dependant biota.
	(c) diversity of important feeding, breeding and nursery sites for native water-dependent biota	The Goulburn River has extensive instream woody habitat within the river channel. This provides substrate for biofilm growth and food and habitat for macroinvertebrates and small fish. It also has many slackwater habitats across a range of low flow magnitudes that are critical habitat for fish larvae.
	(d) diversity of aquatic environments including pools, riffle and run environments	The Goulburn River has a high diversity of aquatic environments. The mid Goulburn is characterised by a series of riffles and pools, and the lower Goulburn has a series of deep pools, slackwater habitats and benches.
	(e) vital habitat that is essential for preventing the decline of native water-dependent biota.	As above
Criterion 2: The ecosystem function supports the transportation and dilution of nutrients, organic matter and sediment		
2	Assessment indicator: An ecosystem function requires environmental watering to sustain it if it provides for the transportation and dilution of nutrients, organic matter and sediment, including: (a) pathways for the dispersal and movement of organic and inorganic sediment, delivery to downstream reaches and to the ocean, and to and from the floodplain	Floods on the lower Goulburn floodplain (reaches 4 and 5) provide organic matter to the Goulburn River and downstream Murray River.
	b) dilution of carbon and nutrients from the floodplain to the river systems.	Delivering freshes during winter and spring assists with moving accumulated organic matter from the lower bank and benches to the river system. This reduces the amount of carbon entering the river system during floods in the warmer summer months.
Criterion 3: The ecosystem function provides connections along a watercourse (longitudinal connections)		
3	Assessment indicator: An ecosystem function requires environmental watering to sustain it if it provides connections along a watercourse or to the ocean, including longitudinal connections: (a) for dispersal and re-colonisation of native water-dependent communities	In recent year Golden perch spawning has been observed downstream of the Goulburn weir (reaches 4 and 5). Other fish species also use the Goulburn River for recruitment (e.g. Murray Cod, Murray Rainbowfish)

	(b) for migration to fulfil requirements of life-history stages	Murray Cod, Golden Perch and Silver Perch have been recorded in the Goulburn River (reaches 4 and 5). These species migrate for breeding; moving to either the Broken River or the Murray River.
	(c) for in-stream primary production.	Delivery of baseflows in both mid and lower Goulburn entrains litter packs for food and habitat for macroinvertebrates. Large woody debris provides habitat for biofilms. Provision of slackwater habitat favourable for planktonic production.
Criterion 4: The ecosystem function provides connections across floodplains, adjacent wetlands and billabongs (lateral connections)		
4	Assessment indicator: An ecosystem function requires environmental watering to sustain it if it provides connections across floodplains, adjacent wetlands and billabongs, including: (a) lateral connections for foraging, migration and re-colonisation of native water-dependent species and communities	There is limited opportunity for lateral connections in the Goulburn River due to the lack of overbank floods. Increased opportunity could be achieved if overbank environmental water deliveries were realised.
	(b) lateral connections for off-stream primary production.	

Appendix 4 Environmental flows and technical studies underpinning flow objectives for the Goulburn River

The first environmental flows study for the Goulburn River was completed in 2003 (Cottingham et al., 2003) and was one of the earliest flows studies in Victoria. This study focused on the mid and lower Goulburn River. Another study was completed in 2007 specifically to assess the impact and management of high summer flows resulting from Inter-Valley Transfers in the lower Goulburn River (GBCMA, 2014b). The method used in the 2007 study differs significantly from that used in 2003.

Changes included:

- Specifying the flow required for each ecological objective instead of identifying a single flow to meet several ecological objectives.
- Providing for inter annual flow variability (dry, medium and wet years).
- Specifying two levels of environmental flow recommendations (the recommended environmental flow to achieve the environmental flow objective with a high degree of confidence (low risk) and a flow that represents a moderate risk to achieving the environmental flow objective. These two levels were provided in recognition of the inherent uncertainty in flow ecology linkages and the need to trade off environmental risks with consumptive water use (GBCMA, 2014b).

As such, the 2007 study provides a complex range of flow recommendations for each ecological objective for different times of year, in different years, and with different levels of risk to the environmental outcomes. Ecological objectives are established for planktonic algae, macrophytes, terrestrial bank vegetation, macroinvertebrates, native fish and geomorphology. The recommendations from the 2007 study have been adopted for the Goulburn River reach from Goulburn Weir to the Murray River (reaches four and five).

A revision of flow recommendations for the mid Goulburn River i.e. Lake Eildon to Goulburn Weir (reaches one to three) was completed in 2014 (Cottingham et al., 2014a). This study made recommendations taking into consideration the use of the river to provide irrigation flows and consequent cold water temperatures.

The 2007 and 2014 studies both recommended a desirable maximum rate of rise and fall in river flows/levels to minimise bank slumping and flushing or stranding of biota. These guide the shaping of flow freshes and water management intervention actions.

In 2007 to 2010, the drought conditions raised ecological questions not previously considered in flows studies. In response a panel of ecologists and hydrologists assessed the impact of low flows to the ecosystem and developed recommendations for water management to minimise the ecological risk in times of drought including the delivery of fresh flows (GBCMA, 2007). In February 2011, the Department of Sustainability and Environment (now Department of Environment, Land, Water and Planning) updated the overbank flow recommendation from the Cottingham et al. (2007) study (GMW, 2012).

Appendix 5 Flow recommendations

The following provides the flow recommendations outlined in Cottingham et al. (2007).

Flow duration bounds identified for Reach 4 ecological objectives.
Note: The values in the table represent the proportion of time that discharge may exceed a particular bound (e.g. 0.85 = 85%). The various percentile years provide opportunities for inter-annual variability, providing different exceedance levels for dry (min, 10th and 30th percentile years) median and wet years (70th, 90th and max years).

			Recommended						
Ecological Objective	Flow Element Code	Discharge (ML/day)	Minimum	10th percentile year	30th percentile year	median year	70th percentile year	90th percentile year	Maximum
Summer - Lower Bound									
MI4	F003b	540		0.90	0.95	0.95	0.98	0.99	
MI1	F007a	310	0.70	0.80	1.00	1.00			
MI3	F007a	310	0.99	0.99	0.99	0.99	0.99		
MI2	F008b	400	0.90	0.93	0.95	0.98	0.98		
n. fish	F008b	400	0.74	0.95	0.99	0.99	0.99		
n. fish	F007b	500	0.97	0.98	0.99	0.99	0.99		
MI6	F003b	540		0.80	0.90	0.95	0.99	0.99	
MI2	F008c	830	0.70	0.93	0.95	0.98	0.98		
Geo3	F026i	856	0.36	0.71	0.94	1.00	1.00	1.0	1.00
Geo3	F026h	1186	0.11	0.57	0.75	0.88	0.96	1.0	1.00
MI1	F007c	1500		0.10	0.30	0.45	0.75		
MI3	F007c	1500		0.15	0.30	0.40	0.70		
Geo3	F026g	1660		0.30	0.47	0.63	0.74	0.94	1.00
Geo3	F026f	2223		0.11	0.25	0.40	0.60	0.71	1.00
Geo3	F026e	3142		0.01	0.06	0.20	0.43	0.55	0.86
Geo3	F026d	4490				0.05	0.24	0.37	0.64
Geo3	F026c	6590					0.08	0.16	0.42
Geo3	F026b	10700						0.04	0.27
Geo3	F026a	19000							
Summer Upper Bound									
Geo3	F026i	856	0.36	0.71	0.94				
Geo3	F026h	1186	0.11	0.57	0.75	0.88	0.96		
MI1	F007c	1500			0.70	0.90	0.90		
Geo3	F026g	1660	0	0.30	0.47	0.63	0.74	0.94	
Geo3	F026f	2223	0	0.11	0.25	0.40	0.60	0.71	
Geo3	F026e	3142	0	0.01	0.06	0.20	0.43	0.55	0.86
Geo3	F026d	4490	0	0	0	0.05	0.24	0.37	0.64
Geo3	F026c	6590	0	0	0	0	0.08	0.16	0.42
Geo3	F026b	10700	0	0	0	0	0	0.04	0.27
Geo3	F026a	19000	0	0	0	0	0	0	0.07
Autumn Lower Bound									
MI2	F008b	400		0.90	0.93	0.95	0.98	0.98	
n. fish	F008b	400		0.99	0.99	0.99	0.99	0.99	
MI4	F003b	540		0.70	0.90	0.95	0.98	0.99	

			Recommended						
MI6	F003b	540		0.70	0.90	0.95	0.99	0.99	
MI2	F008c	830		0.50	0.65	0.80	0.95	0.98	
Winter Lower Bound									
n. fish	F008b	400		0.99	0.99	0.99	0.99	0.99	
n. fish	F007b	500		0.80	0.86	0.88	0.90	0.96	
MI4	F003b	540		0.85	0.90	0.95	0.98	0.99	
MI6	F003b	540		0.80	0.90	0.95	0.99	0.99	
MI2	F008c	830		0.90	0.93	0.95	0.98	0.98	
Spring Lower Bound									
n. fish	F008b	400		0.99	0.99	0.99	0.99	0.99	
MI2	F008b	400		0.90	0.93	0.95	0.98	0.98	
n. fish	F008b	400		0.99	0.99	0.99	0.99	0.99	
n. fish	F007b	500		0.81	0.85	0.91	0.95	0.99	
MI4	F003b	540		0.70	0.90	0.95	0.98	0.99	
MI6	F003b	540		0.70	0.90	0.95	0.99	0.99	
MI2	F008c	830		0.90	0.93	0.95	0.98	0.98	
n. fish	F027a	24000				0.05	0.13	0.31	
Spring Upper Bound									
n. fish	F027a	24000		0	0	0.08	0.19	0.47	

Flow duration bounds identified for Reach 5 ecological objectives.
The values represent the proportion of time that discharge may exceed a particular bound (e.g. 0.85 = 85%). The various percentile years provide opportunities for inter-annual variability, providing different exceedance levels for dry (min, 10th and 30th percentile years) median and wet years (70th, 90th and max years).

			Recommended						
Environ. Objective	Flow Element Code	Flow Threshold (Ml/day)	Minimum	10th percentile year	30th percentile year	median year	70th percentile year	90th percentile year	Maximum
Summer - Lower Bound									
MI1	F007a	240		0.70	0.80	1.00	1		
MI3	F007a	240		0.99	0.99	0.99	0.99	0.99	
n. fish	F007b	320		0.90	0.90	0.99	0.99	0.99	
MI2	F008b	540		0.90	0.92	0.95	0.98	0.98	
n. fish	F008b	540		0.99	0.99	0.99	0.99	0.99	
MI4	F003b	770		0.90	0.95	0.95	0.98	0.99	
MI6	F003b	770		0.80	0.90	0.95	0.99	0.99	
MI2	F008c	940		0.70	0.92	0.95	0.98	0.98	
Geo3	F026i	1096	0.38	0.75	0.88	0.96	1.00	1.00	1.00
Geo3	F026h	1505	0.17	0.53	0.64	0.82	0.94	1.00	1.00
Geo3	F026g	1993	0.02	0.17	0.40	0.60	0.73	0.97	1.00
Geo3	F026f	2711	0	0.09	0.21	0.35	0.60	0.87	1.00
Geo3	F026e	3800	0	0	0.05	0.20	0.40	0.66	1.00
Geo3	F026d	5240	0	0	0	0.02	0.22	0.43	0.71
Planktonic Algae	F002c	6060				0	0.17		
Geo3	F026c	7560	0	0	0	0	0.08	0.18	0.47
Geo3	F026b	13000	0	0	0	0	0	0.03	0.38
Geo3	F026a	23900	0	0	0	0	0	0	0.09
Summer - Upper Bound									
Geo3	F026i	1096	0.38	0.75	0.88	0.96	1.00	1.00	1.00
Geo3	F026h	1505	0.17	0.53	0.64	0.82	0.94	1.00	1.00
Geo3	F026g	1993	0.02	0.17	0.4	0.60	0.73	0.97	1.00
Geo3	F026f	2711	0	0.09	0.21	0.35	0.60	0.87	1.00
Geo3	F026e	3800	0	0	0.05	0.20	0.40	0.66	1.00
Geo3	F026d	5240	0	0	0	0.02	0.22	0.43	0.71
MI2	F004c	5610		0.01	0.01	0.02	0.30	0.50	
MI4	F004c	5610		0.01	0.01	0.02	0.25	0.45	
Planktonic algae	F002c	6060					0.19	0.30	
Geo3	F026c	7560	0	0	0	0	0.08	0.18	0.47
MI2	F002b	8910		0.01	0.01	0.01	0.05	0.15	
Geo3	F026b	13000	0	0	0	0	0	0.03	0.38
Geo3	F026a	23900	0	0	0	0	0	0	0.09
Autumn - Lower Bound									
n. fish	F007b	320		0.99	0.99	0.99	0.99	0.99	
MI2	F008b	540		0.90	0.92	0.95	0.98	0.98	

			Recommended						
n. fish	F008b	540		0.99	0.99	0.99	0.99	0.99	
MI4	F003b	770		0.70	0.90	0.95	0.98	0.99	
MI6	F003b	770		0.70	0.90	0.95	0.99	0.99	
MI2	F008c	940		0.50	0.65	0.80	0.95	0.98	
Autumn - Upper Bound									
MI2	F004c	5610		0.01	0.01	0.02	0.30	0.60	
MI4	F004c	5610					0.03	0.10	
MI2	F002b	8910		0.01	0.01	0.01	0.01	0.05	
n. fish	F007b	320		0.99	0.99	0.99	0.99	0.99	
n. fish	F008b	540		0.99	0.99	0.99	0.99	0.99	
MI4	F003b	770		0.85	0.9	0.95	0.98	0.99	
MI6	F003b	770		0.8	0.9	0.95	0.99	0.99	
MI2	F008c	940		0.9	0.92	0.95	0.98	0.98	
Winter - Upper Bound									
MI2	F002b	8910		0.2	0.3	0.65	0.8	0.9	
n. fish	F007b	320		0.99	0.99	0.99	0.99	0.99	
MI2	F008b	540		0.9	0.92	0.95	0.98	0.98	
n. fish	F008b	540		0.99	0.99	0.99	0.99	0.99	
n. fish	F008b	540		0.99	0.99	0.99	0.99	0.99	
MI4	F003b	770		0.70	0.90	0.95	0.98	0.99	
MI6	F003b	770		0.70	0.90	0.95	0.99	0.99	
MI2	F008c	940		0.90	0.92	0.95	0.98	0.98	
Planktonic algae	F002c	6060							
MI4	F004c	5610		0.42	0.70	0.85	0.95	1.00	
Plankt. algae	F002c	6060		0.35	0.66	0.73	0.86	1.00	
MI2	F002b	8910		0.10	0.40	0.65	0.80	1.00	
n. fish	F027a	24000		0	0.05	0.13	0.26	0.54	

Flow stressors and their components

Code	Description	Elements
F001	Mean hydraulic residence time (hours/km)	-
F002	Proportion of time when euphotic depth is less than n times the mean depth	n = 0.2, 0.25, 0.3
F003	Proportion of time when mean shear stress is less than n N/m^2 - leading to deposition of fine sediments	n = 1, 2, 3
F004	Proportion of time when mean shear stress is more than n N/m^2 – leading to possibly biofilm instability	n = 5, 6, 7
F005	Water level fluctuation characterised by the amphibious habitat index calculated at euphotic depth for the n% exceedance flows (in the pre-regulation regime)	n = 10, 20, 30, …, 90
F006	Maximum inundation duration at heights up the bank corresponding to the water surface levels for the n% exceedance flows (in the pre-regulation regime)	n = 10, 20, 30, …, 90
F007	Proportion of time when there is less than n m^2/m slow shallow habitat (d<0.5 m, v<0.05 m/s).	n = 1, 2, 3, …, 5
F008	Proportion of time when there is less than n m^2/m deep water habitat defined as d>1.5 m	n = 5, 10, 15, 20
F009	Maximum continuous rise in stage (m)	-
F010	The distribution of daily change in stage characterised by the n^{th} percentile values (m)	n = 10, 90
F011	mean illuminated volume of water (m^3 per m length of channel)	-
F012	mean ratio of euphotic depth to mean water depth	-
F013	mean ratio of fall velocity (n m/s) to mean water depth	n = 0.2, 0.4 and 0.94
F014	mean illuminated area of benthos (m^2 per m length of channel)	-
F015	mean illuminated area of benthos with velocity less than n m/s (m^2 per m length of channel)	n = 0.2, 0.3, 0.4 and 0.9
F016	proportion of time when benthos has been in euphotic zone for at least n days, calculated for water surface levels corresponding to the m% exceedence flows (in the pre-regulation regime)	n = 14 and 42 m = 10, 20, 30, …, 90
F017	Number of independent events when benthos has been in euphotic zone for at least n days, calculated for water surface levels corresponding to the m% exceedence flows (in the pre-regulation regime)	n = 14 and 42 m = 10, 20, 30, …, 90
F018	Mean water depth (m) during periods when benthos is in euphotic zone for at least n days calculated for water surface levels corresponding to the m% exceedence flows (in the pre-regulation regime)	n = 14 and 42 m = 10, 20, 30, …, 90
F019	proportion of time benthos is in the euphotic zone, calculated for water surface levels corresponding to the m% exceedence flows (in the pre-regulation regime)	m = 10, 20, 30, …, 90
F020	Proportion of time benthos is below the euphotic zone, calculated for water surface levels corresponding to the m% exceedence flows (in the pre-regulation regime)	m = 10, 20, 30, …, 90
F021	number of overbank events	
F022	The distribution of daily rises in stage characterised by the n^{th} percentile values (m)	n = 10, 90
F023	The distribution of daily falls in stage characterised by the n^{th} percentile values (m)	n = 10, 90
F024	The distribution of daily falls in stage characterised by the n^{th} percentile values (m) for flow bands defined by the flows Qi ML/day	n = 10, 50, 90 = 0, 4000, 100000
F025	Proportion of time water level is within a range defined by water surface levels corresponding to the m% exceedence flows (in the pre-regulation regime)	m = 10, 20, 30, …, 90
F026	Proportion of time water level is above a specified depth above bed corresponding to the m% exceedence flows (in the pre-regulation regime)	m = 10, 20, 30, …, 90
F027	Proportion of time flow exceeds 24000 ML/day	

Relationships between ecological values, ecological objectives and flow stressors

Ecological Value	Code	Ecological Objective	Stressor code(s)	Seasons	Stressor mechanism
Source of food for fish and invertebrates and influence on river nutrient and chemical conditions	Planktonic algae	Production rates, biomass levels and community composition more resembling un-impacted sites and dynamic diverse food webs	F001	Sum, Spr	Increased channel retention due to reduced water velocity and/or hydraulic retention zones allows accumulation of biomass if growth rates exceed loss rates.
			F002	Sum, Spr	Proportion of time planktonic algae spend in the euphotic zone determines whether net production is possible or not
			F012	Spr	Proportion of time planktonic algae spend in the euphotic zone multiplied by mean surface irradiance determines the relative level of production
			F013	Sum, Spr	Water depth influences the rate of deposition of planktonic algae (It takes longer for settling in deeper water)
Source of food for fish and invertebrates, habitat, and influence on river nutrient and chemical conditions	Periphytic algae	Production rates, biomass levels and community composition more resembling un-impacted sites and dynamic diverse food webs	F014	Sum, Spr	Benthic production is restricted to wetted perimeter within the euphotic zone (i.e. where light penetrates to the channel bed and banks)
			F015	Sum, Spr	High velocities influencing biofilm stability. Area of colonization determined by extent of light zone - use euphotic depth, but limited by velocity.
			F016	Spr	Establishment of biofilms requires that the wetted surface remains wet and within the euphotic depth for a period of some time. Drying and submersion below the euphotic depth will adversely affect biofilms
Contributes to primary production, habitat for macroinvertebrates and native fish	Macrophytes	Production rates, biomass levels and community composition more resembling un-impacted sites and dynamic diverse food webs	F014	All	Benthic production is restricted to wetted perimeter within the euphotic zone (i.e. where light penetrates to the channel bed and banks)
			F015	Sum, Aut, Spr	High velocities influencing biofilm stability. Area of colonization determined by extent of light zone - use euphotic depth, but limited by velocity.
			F016	Sum, Aut, Spr	Establishment of aquatic macrophytes requires that the wetted surface remains wet and within the euphotic depth for a period of some time. Drying and submersion below the euphotic depth will adversely affect macrophytes
Natural gradient of native terrestrial vegetation up the river banks	Terrestrial bank vegetation	Maintain native terrestrial cover at top of banks and reduce cover of terrestrial vegetation in areas of the bank influenced by flow regulation	F006	Sum, Aut (Dec-Apr)	Duration of submergence (inundation) has potential to drown out terrestrial vegetation, due to carbon and oxygen starvation; critical values for duration tolerance expected to vary between seasons, being much longer in cool (autumn-winter) than in warm growing (spring-summer) season.

Ecological Value	Code	Ecological Objective	Stressor code(s)	Seasons	Stressor mechanism
Diverse and resilient aquatic macroinvertebrate fauna	MI1	Provision of conditions suitable for aquatic vegetation, which provides habitat for macroinvertebrates	F007	Sum	Slow shallow velocities required for establishment of aquatic vegetation
			F010	Win	Short-term flow fluctuations can adversely affect aquatic vegetation growing along the channel margins
			F022	All	Short-term flow fluctuations can adversely affect aquatic vegetation growing along the channel margins
			F023	All	Short-term flow fluctuations can adversely affect aquatic vegetation growing along the channel margins
	MI2	Submersion of snag habitat within the euphotic zone to provide habitat and food source for macroinvertebrates	F002	All	Quantity and variety of snags dependent on volume (possibly modified by biodiversity and productivity of snag biofilm - depth and variability of light climate).
			F004	Sum, Aut	High shear stresses can lead to biofilm instability
			F008	All	Loss of pools
			F025	Sum, Aut (Dec-Apr)	Reduction in flow result in drying of large woody debris
	MI3	Provision of slackwater habitat favourable for planktonic production (food source) and habitat for macroinvertebrates (MI3)	F007	Su	Increased flow velocity and rapid rates of rise and fall affect availability of shallow, slackwater habitat for macroinvertebrates.
			F023	All	daily fall in stage
			F024	Sum, Aut (Dec-Apr)	daily fall in stage
	MI4	Entrainment of litter packs available as food/habitat source for macroinvertebrates (MI4)	F003	All	Shear stress required to disrupt (refresh) biofilms and entrain organic matter.
			F004	Sum, Aut, Spr	Shear stress required to disrupt (refresh) biofilms and entrain organic matter.
			F021	All	Overbank events may entrain organic matter
	MI6	Maintenance of water quality suitable for macroinvertebrates	F003	All	Temperature, nutrients and salinity assumed not significant, pollution effects (toxicants) not known. Sediment deposition noted and known to remove susceptible taxa.
Diversity of native species, naturally self-reproducing populations of native fish, threatened and iconic native species.	Native Fish	Suitable in-channel habitat for all life stages	F007	All	Slow shallow habitat required for larvae/juvenile recruitment and adult habitat for small bodied fish
			F008	All	Deep water habitat for large bodied fish
		Cues for adult migration during spawning season	F022	Sum, Spr	Flow variation required as a cue for migration and spawning
			F023	Sum, Spr	Flow variation required as a cue for migration and spawning

Ecological Value	Code	Ecological Objective	Stressor code(s)	Seasons	Stressor mechanism
		Suitable off-channel habitat for all life stages	F027	Spr	Inundation of floodplain required by some species and for transport of nutrients and organic matter to drive food webs
Natural Channel Form and Dynamics	Geo1	Avoid notching	F025	Sum, Aut (Dec-Apr)	Long duration of stable flow followed by rapid draw-down. Impact likely to be exacerbated by loss of bank side vegetation.
	Geo2	Avoid slumping	F023	Sum	Excessive rates of fall in river level.
	Geo3	Maintain pool depth	F026	Sum	Unseasonal events that fill pools with sediment but do not flush them.
	Geo6	Maintain natural rates of geomorphic disturbance	F006	Sum, Aut (Dec-Apr)	High velocity discharge increases disturbance of sand substrates and aquatic macrophytes.

The table below provides a summary of flow-related ecosystem objectives and associated flow components. Followed by tables providing the flow recommendations for the mid Goulburn River outlined in Cottingham et al. (2014b).

Ecosystem Attribute	Environmental or Ecological Values	Potential flow related threats	Flow-related ecological objectives	Reach	Flow Component to be considered	Mechanism	Season
Geomorphology	Geomorphic processes contribute to the availability and quality of in-channel and riparian habitat	Reduced frequency of flow events capable of providing diverse bed morphology.	**G1**: Scour surficial and interstitial fine sediment from riffles.	All	Freshes	Flows of sufficient magnitude to provide critical shear stress to periodically mobilise fine sediments.	Win, Spr
			G2: Overturn of bed substrate (gravels to cobbles).	All	Bank full, Overbank	Flows of sufficient magnitude to provide critical shear stress to	Win, Spr

Ecosystem Attribute	Environmental or Ecological Values	Potential flow related threats	Flow-related ecological objectives	Reach	Flow Component to be considered	Mechanism	Season
		Reduced frequency of flow events that maintain connectivity with riparian and floodplain habitats.				periodically disrupt pebbles and cobbles.	
			G3: Maintain channel form and key habitats, including in-channel benches.	All	High flows, Bank full	Flows of sufficient magnitude and duration to maintain channel form.	Win, Spr
			G4: Movement of bed material to maintain bed diversity for water depth variation, including scour of sediments from base of pools, to maintain quantity and quality of habitat for flora and fauna.	All	High flows, Bank full, Overbank	Flows of sufficient magnitude to provide critical shear stress to scour sediments from pools.	Win, Spr
			G5: Maintain channels and inlets for connectivity of main channel with important floodplain and wetland zones and tributaries.	All	High flows, Bank full, Overbank	Flows of sufficient magnitude to provide critical shear stress to periodically mobilise sand.	Win, Spr
Water Quality	Integral component of aquatic habitat for flora and fauna	Unseasonal flows combined with factors such as poor quality catchment runoff. Most likely to be affected by localised and catchment runoff (all reaches) and operation of Lake Eildon (Reach 1).	**WQ1**: Investigate role of water releases in addressing instances of DO falling below 4 mg/L.	1	Baseflow (low flow)	Investigate potential for release of high-DO water from Lake Eildon address instances of low DO.	All (particularly Sum, Aut)
Riverine vegetation	Intrinsic value of native vegetation Preservation of endangered EVCs and species	Decreased incidence of winter-spring flows, with impacts on freshes. Decreased incidence of bankfull and overbank flows.	**RV1**: Maintain existing beds of in-channel macrophytes as a habitat and for biodiversity reasons.	1, 2	Baseflow, Freshes, Bankfull flows	Provide variability in inundation to maintain adults and to permit sexual recruitment of juveniles into the population (e.g. seed generation and dispersal).	Win, Spr, Sum

Ecosystem Attribute	Environmental or Ecological Values	Potential flow related threats	Flow-related ecological objectives	Reach	Flow Component to be considered	Mechanism	Season
	Protection against bank/channel erosion and sediment suspension Interception of catchment-derived nutrients and sediments Provision of faunal habitat	Decrease in baseflow variability.				Provide scouring flows to remove excessive growth of filamentous algae (Reach 1)	
			RV2: Provide periodic regeneration opportunities for native riparian species adapted to and dependent on the natural flow regime (riparian and floodplain wetland).	All	Bankfull flows, Overbank flows	Riparian vegetation (canopy layer as well as understory) generally requires periodic inundation to maintain good condition of adults and to permit sexual recruitment of juveniles into the population.	Spr
			RV3: Provide periodic overbank flows to improve in-channel carbon availability.	All	Overbank flows (to inundate floodplain more generally)	Connection to wetland and low-lying floodplain areas will add to the variety and loading of carbon in the river.	Win, Spr
			RV4: Maintain diversity among low-lying wetlands by providing different water regimes.	All	Baseflow (high flows) and variability therein, Overbank flows and variability therein (including inter-annual and within-year variability)	Increase lateral continuity to permit movement of adults and propagules for full ecological functioning, including increased productivity.	Win, Spr
Invertebrates	Important indicator of river health Food source for fish, including threatened species and important recreational species	Reduced frequency of flow events capable of scouring sediments from pools. Longer than natural duration of low flow events, resulting in excessive deposition of fine materials.	**I1**: Maintain areas of riffle habitat.	1, 2	Baseflow (low flow)	Flows of sufficient magnitude wet riffle habitat.	Win, Spr
			I2: Scour gravels to remove fine sediments from interstitial spaces (improve habitat quality)	All	High flow freshes	Flows of sufficient magnitude to provide critical shear stress to scour fine sediments from the substrate.	Win, Spr

Ecosystem Attribute	Environmental or Ecological Values	Potential flow related threats	Flow-related ecological objectives	Reach	Flow Component to be considered	Mechanism	Season
		Reduced frequency of flow events that maintain connectivity with riparian and wetland habitats.	**I3**: Maintain habitat for macrophytes that provide crucial habitat for macroinvertebrates	All	Baseflow (low flow) and natural seasonality	As for RV objectives.	Spr, Sum, Aut
			I4: Scour fine sediment from the surface of the riffle substrate to maintain habitat quality	All	Freshes (low flow and high flow)	Flows of sufficient magnitude to provide critical shear stress to scour fine sediments from the substrate.	Win, Spr, Sum, Aut
			I5: Retain natural seasonality to ensure synchronicity of life cycle stages with appropriate flows	All	Baseflow (low flows and high flows)	Flow regime with components that have natural features of timing, frequency, magnitude and duration.	Win, Spr, Sum, Aut
			I6: Provide floodplain connection for exchange of organic matter and fine sediment	All	Bankfull and overbank flows	High flows into flood runners and overbank flows onto the floodplain.	Win, Spr
			I7: Scour filamentous algae and biofilm to promote productivity	All	Spring and summer freshes	Velocity and shear stress required to disrupt filamentous algae	Win, Sum
Native fish	Native fish contribute to aquatic biodiversity, are key predator in aquatic food webs, valued for recreational fishing. In particular, Murray cod, Trout cod and Macquarie perch are listed as vulnerable or threatened and are the focus of management objectives in	Unseasonal flow regime (including low winter flows) that reduces habitat availability and connectivity, as well as leads to miscued/lack of spawning opportunities. High summer flows which reduce riverine productivity at a range of trophic scales.	**NF1**: Increase flow variability to more closely mimic natural hydrological regime	All	All	Flow regime with components that have natural features of timing, frequency, magnitude and duration.	All
			NF2: Maintain or increase connection to water temperature refuges	All	Bankfull, Overbank, Low flows (summer-autumn winter-spring)	Flow of sufficient magnitude to connect channel to riparian and wetland refugia.	Win, Spr

Ecosystem Attribute	Environmental or Ecological Values	Potential flow related threats	Flow-related ecological objectives	Reach	Flow Component to be considered	Mechanism	Season
	the Goulburn-Broken Regional Waterway Strategy.	Reduced frequency of connection with wetland habitats.				Variability to provide connection for longitudinal movement along the river Variability to provide connection with tributaries	Sum, Aut Win, Spr
			NF3: Provide flows to promote colonisation by large-bodied endangered species	All	Freshes	Flow of sufficient magnitude to provide migration cues; depth across the channel sufficient for fish passage.	Spr
			NF4: Low summer flows to increase recruitment of low flow specialists (primarily in off-channel areas)	All	Baseflow, Bankfull, Overbank	Flow of sufficient magnitude to inundate flood runners and low-lying floodplain wetlands.	Win, Spr
			NF5: Provision of lateral connectivity to increase primary and secondary production and as habitat for small bodied fishes	All	Bankfull, Overbank	Flow of sufficient magnitude to inundate flood runners and floodplain wetlands.	Win, Spr
			NF6: Maintain riffle habitat outside of the irrigation season	All	Winter-spring baseflow	Flow of sufficient magnitude to wet riffle habitat.	All
			NF7: Promote Macquarie perch spawning	2, 3	Spring fresh, Summer base flow	Fresh of sufficient magnitude to cue breeding and spawning, base flow to provide access to edge and slackwater habitat	Spr, Sum

Environmental flow recommendations for Reach 1: Lake Eildon to Yea River

Objectives (features addressed in parenthesis)	Main Flow Components	Flow Recommendation	Rationale
Recommendations for Baseflow			
NF6, RV1, I1, I2, I4 (wet riffles, maintain baseflow wetted area, maintain existing aquatic vegetation)	Baseflow (all seasons)	Minimum flow of 400 ML/day, or natural (whichever is lower), outside of the irrigation season.	Based on HECRAS wetted perimeter of riffle cross-sections (4.6 cumecs to inundate riffles in cross-sections) – based on the breakpoint of wetted perimeter-discharge. Provides wetted area for River blackfish and galaxids, and also supports aquatic vegetation and invertebrates (including Spiny crayfish). A baseflow of 400 ML/day in Reach 1 provides almost double the area of wetted habitat from that wetted at the current minimum flow of 120 ML/day.
T1 (maintain redds)	Winter baseflow	Range: 500 ML/day - 5000 ML/day.	Based on Brown (2003), and spawning expected in May-June; the intention is to maintain flows to avoid drying out of redds (500 - 5000 ML/day).
T2 (trout fry survival)	Spring-summer baseflow	Maintain baseflow <3000 ML/day between September and February; delay flow above this as long as possible into irrigation season.	Peak fry habitat at 450-1000 ML/day in Sept to Feb based on Brown (2003) habitat suitability curves for wild population recruitment. The intent is to provide flows that cover bottom of the channel. Based on break of wetted perimeter-discharge relationship from HECRAS, this requires 2000-3000 ML/day.
T3 (prevent angler overexploitation)	Summer-autumn baseflow	Maintain baseflow >4000 ML/day approximately 1 year in 3 or 4 to maintain density of larger trout in population.	Wading depth for anglers. Based on expert opinion. Safe wading velocity (ft/sec)* depth (ft) <10. <1 m/s or less on bars and riffles for safe wading.
Recommendations for Freshes			
G1, I3, I4 (scour fine sediments, maintain interstitial spaces for invertebrates)	Winter-spring freshes	Peak magnitude: 900 ML/day. Frequency: depends on antecedent conditions. Duration: 1 day. Timing: depends on tributary inputs – following cessation of high tributary inflows (e.g. flows of approximately 4000 ML/day from the Acheron River) if flows in Reach 1 are below 900 ML/day for 1 month.	Wilkinson and Rutherfurd (2001) identified shear stress of 15 Nm^2 to scour fine sediments. HECRAS indicates this occurs at approximately 12000 ML/day along Reach 1 generally but that 15 Nm^2 can be achieved over one small riffle at 800-900 ML/day. This suggests that small pulses can still be useful for maintaining habitat quality.

Objectives (features addressed in parenthesis)	Main Flow Components	Flow Recommendation	Rationale
I1 (sloughing filamentous algae and refreshing of biofilms)	Summer-autumn and winter-spring freshes	Peak magnitude: 2500 ML/day. Frequency: 2 per year Duration: 5 days (dry years) to 7 days (average, wet years). Timing: 1 in spring and 1 in summer-autumn.	Sloughing of filamentous algae can occur at water velocity of 0.55 m/s (based on Ryder et al. 2006). From HECRAS, with reach mean velocity of 0.6 m/s. Duration of between 5-7 days represents maximum duration that occurs in dry years and the median that occurs in all years:
Recommendations for Bankfull and Overbank flows			
G3 (maintenance of in-channel benches)	Close to winter-spring bankfull	Peak magnitude: 7000 – 9000 ML/day Frequency: as in G2 bankfull component. Duration: 2 days. Timing: as in G2 bankfull component. Rise and fall: as in G2 bankfull component.	From HECRAS model; depth 0.0-0.5 m above bench levels (Vietz et al. 2012). Preference is to coincide (piggy back) with or follow soon after high tributary inflows so that suspended sediment from tributary catchments is dropped onto benches (and reduce the sediment otherwise smothering the bed).
G2, G4, G5 (disruption of river channel armour layer, movement of bed material, scouring of pools)	Winter-spring bankfull and overbank flows	**Bankfull** Peak magnitude: 11 000 ML/day Frequency: 1 event in 2 out of 3 years, but secondary to other objectives (e.g. wetland inundation). Duration: 1 day at peak flow. Rise and fall: Rise (Q_2/Q_1) = maximum of 2.0-2.7; Fall (Q_2/Q_1) = maximum of 0.8. **Overbank** Peak magnitude: up to 20 000 ML/day Frequency: 1 every three years in dry years, 1 in 2 years in average and wet years. Duration: 1 day at peak flow. Timing: Any time – can coincide with other requirements such as wetland inundation. Rise and fall: Rise (Q_2/Q_1) = maximum of 2.0-2.7; Fall (Q_2/Q_1) = maximum of 0.8.	Overall, there is very little ability to change bed morphology, except at flows above bankfull up to 20 000 ML/day. Shear stress to turn over pebbles (up to 64 mm) in riffles equals 64 Nm^2, from HECRAS model. Modelling indicates that flows greater than bankfull are required for move pebbles – in-channel flows do not have competence to move 100% pebbles. To move 50% of pebbles/cobbles in Reach 1 requires approximately 10 000 ML/day (almost bankfull). Bankfull – Rationale for frequency – unimpacted regime gets average of 3 events per year in 96% of years. Get events in most dry years. Overbank – rationale for frequency – unimpacted regime gets 3 events in 80% of years. Adopt 15 000 initially to avoid excessive watering, particularly in Reach 2, and measure response before moving to larger events up to 20 000 ML/day. Rise and fall – examined current GMW rules and rates proposed by Cottingham et al. (2003); applied a more conservative rate of fall than both sources to account for variability in riparian zone condition and potential for increased rates of mass failure bank erosion.

Objectives (features addressed in parenthesis)	Main Flow Components	Flow Recommendation	Rationale
			To concomitantly reduce sediment smothering from high sediment load tributary inflows, delivery is recommended on the receding limb of tributary inflow dominance of flows along the river and just before releases from Lake Eildon start to dominate flows in the river. This timing likely to be winter-spring and can be beneficial for invertebrates and fish also.
NF1 (increased flow variability)	All components	Covered by a combination of all previous objectives and remaining NF objectives.	As for all previous objectives
NF2, NF4, NF5 (maintain or increase connection to fish habitats)	Winter-spring bankfull, overbank	**Bankfull** Peak magnitude: 11000 ML/day. Frequency and timing: Annually preferred, but accept less frequent occurrence to balance with other objectives (e.g. wetland filling only once or drying phase, Macquarie perch breeding). At least 2 events in a year (August and March/April, if not connected earlier in summer) if pursuing this objective. Duration: as for RV 2 (below). Timing: and as in rationale. Rise and Fall: As for G2 (above). **Overbank** Peak magnitude: 15000 ML/day. Frequency: as for RV2. Duration: as for RV2. Timing: winter-spring, and as in rationale. Rise and fall: as for G2.	The intention of the bankfull flow is to connect the river to anabranches and low-lying wetlands at start and end of season the irrigation season to prevent complete wetland drying and allow fish to move between the river channel and anabranch and wetland habitat.
RV2, RV3, RV4, RV5, I5, I6 (wetting of riparian zone and wetlands, regeneration of native woody species, entrainment of organic matter)	Winter-spring bankfull and overbank	**Bankfull** Peak magnitude: 11000 ML/day. Frequency: Average and wet years: 1 event in 2 years Dry years: 1 event in 3 years in, Maximum interval of 1 in 7 years. Duration: 4 days. Timing: winter-spring, and as in rationale. Rise and Fall: as for G2. **Overbank** Peak magnitude: 20000 ML/day. Frequency: Events up to 15000 ML/day: 1 in 2 years for average and wet years, 1 in 3 years for dry years	The intent is to increase variability in regulated flows, and meet the needs of native woody species (Roberts and Marston 2011, Greet 2012). The aim is to deliver events of 10000 ML/day and greater, and then draw down to approximately 5000 ML/day, with drawdown before Lake Eildon releases dominate river flows so that flow variability and vegetation diversity are promoted.

Objectives (features addressed in parenthesis)	Main Flow Components	Flow Recommendation	Rationale
		Events up to 20000 ML/day: 1 in 5 years for average and wet years (not in dry years). Duration: 4 days. Timing: winter- early spring, with recession through October. Rise and fall: as for G2.	

Environmental flow recommendations for Reach 2: Yea River to Sunday Creek (Seymour)

Objectives (habitat feature in parenthesis)	Main Flow Components	Flow Recommendation	Rationale
Recommendations for Baseflow			
NF6, RV1, I2, I4 (riffles, baseflow wetted area)	Baseflow (all seasons)	Minimum flow of 500 ML/day, or natural (whichever is lower), outside of the irrigation season.	Based on HECRAS wetted perimeter of riffle cross-sections (4.6 cumecs to inundate riffles in cross-sections) – based on the breakpoint of wetted perimeter-discharge. Provides wetted area for Blackfish and galaxids, and also supports aquatic vegetation and invertebrates (including Spiny crayfish).
Recommendations for Freshes			
I1, NF1 (sloughing filamentous algae and refreshing of biofilms)	Summer-autumn and winter-spring freshes	Peak magnitude: 2500-3500 ML/day. Frequency: 2 per year Duration: 5 days (dry years) to 7 days (average, wet years). Timing: 1 in winter-spring and 1 in summer-autumn.	Sloughing of filamentous algae can occur at water velocity of 0.55 m/s (based on Ryder et al. 2006). From HECRAS, with reach mean velocity of 0.6 m/s. Duration of between 5-7 days represents maximum duration that occurs in dry years and the median that occurs in all years.
NF3, NF7 (attractant flows for large-bodied native fish, Macquarie perch spawning)	Spring freshes	Peak magnitude: 0.5 m increase in stage height over one week in late spring (Oct-Dec), assuming temperature is suitable (e.g. above 16^{0}C). Duration: 1 week of rise and hold for two days at the target flow, if this does not happen earlier in spring. Rise and fall: as for G2.	Expert opinion based on attracting flow from potential colonists noted in the Murray River (Lyon et al. 2014; Koster et al. 2012). Macquarie perch spawning based on flow recs from the Yarra River. King et al. (2011) (cited in SKM 2012) noted that strongest recruitment occurred following spring high flows that promoted spawning (and cleaned spawning sites) followed by relatively stable (but not static) summer flows that reduced the likelihood of eggs being washed away.
Recommendations for Bankfull and Overbank flows			
G2, G3, G4, G5 (disruption of river channel armour layer, movement of bed material, scouring of pools)	Winter-spring bankfull and overbank flows	**Bankfull** Peak magnitude: 11000 ML/day Frequency: 1 event in 2 out of 3 years, but secondary to other objectives (e.g. wetland inundation). Duration: 2 days at peak flow. Rise and fall: governed by Reach 1 and tributary inputs. **Overbank** Peak magnitude: 15000 ML/day.	From HECRAS model; depth 0.0-0.5 m above bench levels (Vietz et al. 2012). Preference is to coincide (piggy back) with or follow soon after high tributary inflows so that suspended sediment from tributary catchments is deposited on benches. Overall, there is very little ability to change bed morphology, except at flows above bankfull up to 20000 ML/day. Shear stress to turn over pebbles (up to 64 mm) in riffles equals 64 Nm^2, from HECRAS model. Modelling indicates that flows greater than

Objectives (habitat feature in parenthesis)	Main Flow Components	Flow Recommendation	Rationale
		Frequency: 1 every three years in dry and average years, 1 in 2 years wet years. Duration: 1 day at peak flow. Timing: Any time – can coincide with other requirements such as wetland inundation. Rise and fall: governed by Reach 1 and tributary inputs.	bankfull are required for move pebbles – in-channel flows do not have competence to move 100% pebbles. To move 50% of pebbles/cobbles in Reach 2 requires approximately 11 000 ML/day (bankfull). Bankfull – Rationale for frequency – unimpacted regime gets average of 3 events per year in 96% of years. Get events in most dry years. Overbank – rationale for frequency – unimpacted regime gets 3 events in 80% of years. Adopt 15 000 initially to avoid excessive watering and assess response before moving to larger events up to 20 000 ML/day that could benefit Reaches 1 and 3. Rise and fall – based on Reach 1; examined current GMW rules and rates proposed by Cottingham et al. (2003); applied a more conservative rate of fall than both sources to account for variability in riparian zone condition and potential for increased rates of mass failure bank erosion. To concomitantly reduce sediment smothering from high sediment load tributary inflows, delivery is recommended at end of tributary inflow dominance of flows along the river and just before releases from Lake Eildon start to dominate flows in the river. This timing likely to be winter-spring and can be beneficial for invertebrates and fish also.
NF1 (increased flow variability)	All components	Covered by a combination of all previous objectives and subsequent NF objectives.	As for all previous objectives
NF2, NF4, NF5 (maintain or increase connection to off-channel fish habitats)	Winter-spring bankfull, overbank	**Bankfull** Peak magnitude: 11 000 ML/day Frequency and timing: Annually preferred, but accept less frequent occurrence to balance with other objectives (e.g. wetland filling only once or drying phase, Macquarie perch breeding). At least 2 events in a year (August and March/April, if not connected earlier in summer) if pursuing this objective. Duration: as for RV 2 (below). Timing: and as in rationale. Rise and Fall: governed by Reach 1 and tributary inputs. **Overbank** Peak magnitude: 15 000 ML/day Frequency: as for RV2. Duration: as for RV2.	As for G2 The intention of the bankfull flow is to connect the river to anabranches and low-lying wetlands at start and end of season the irrigation season to prevent complete wetland drying and allow fish to move between the river channel and anabranch and wetland habitat.

Objectives (habitat feature in parenthesis)	Main Flow Components	Flow Recommendation	Rationale
		Timing: winter-spring, and as in rationale. Rise and fall: governed by Reach 1 and tributary inputs.	
RV2, RV3, RV4, RV5, I5 (wetting of riparian zone and wetlands, regeneration of native woody species, entrainment of organic matter)	Winter-spring bankfull and overbank	**Bankfull** Peak magnitude: 11000 ML/day Frequency: Average and wet years: 1 event in 2 years Dry years: 1 event in 3 years in, Maximum interval of 1 in 7 years. Duration: 4 days. Timing: winter-spring, and as in rationale. Rise and Fall: governed by Reach 1 and tributary inputs. **Overbank** Peak magnitude: 15000 ML/day Frequency: 1 in 2 years for average and wet years, 1 in 3 years for dry years, maximum interval of 1 in 7 years. Duration: 4 days. Timing: winter- early spring, with recession through October Rise and fall: governed by Reach 1 and tributary inputs.	The intent is to increase variability in regulated flows, and meet the needs of native woody species (Roberts and Marston 2011, Greet 2012). The aim is to deliver events of 10000 ML/day and greater, and then draw down to approximately 5000 ML/day, with drawdown before Lake Eildon releases dominate river flows so that flow variability and vegetation diversity are promoted.

Environmental flow recommendations for Reach 3: Sunday Creek (Seymour) to Goulburn Weir

Objectives (habitat feature in parenthesis)	Main Flow Components	Flow Recommendation	Rationale
Recommendations for Baseflow			
NF6, RV1, I2, I4 (riffles, baseflow wetted area)	Baseflow (all seasons)	Minimum flow of 800 ML/day, or natural (whichever is lower), outside of the irrigation season.	Based on HECRAS wetted perimeter of riffle cross-sections (4.6 cumecs to inundate riffles in cross-sections) – based on the breakpoint of wetted perimeter-discharge. Provides wetted area for small-bodied fish and invertebrates.
Recommendations for Freshes			

Objectives (habitat feature in parenthesis)	Main Flow Components	Flow Recommendation	Rationale
NF3, NF7 (attractant flows for large-bodied native fish, Macquarie perch spawning)	Spring freshes	Peak magnitude and timing: 0.5 m increase in stage height over one week in late spring (Oct-Dec), assuming temperature is suitable (e.g. above 16^{0}C). Duration: 1 week of rise and hold for two days at the target flow, if this does not happen earlier in spring. Rise and fall: as for G2.	Expert opinion based on attracting flow from potential colonists noted in the Murray River (Lyon et al. 2014; Koster et al. 2012). Macquarie perch spawning based on flow recs from the Yarra River. King et al. (2011) (cited in SKM 2012) noted that strongest recruitment occurred following spring high flows that promoted spawning (and cleaned spawning sites) followed by relatively stable (but not static) summer flows that reduced the likelihood of eggs being washed away.
NF1 (maintain fish growth)	Summer-autumn freshes	As per Reach 2	As per Reach 2
Recommendations for Bankfull and Overbank flows			
G3, I1, NF3, NF7 (maintenance of in-channel benches, slough filamentous algae and resent biofilms)	Approaching winter-spring bankfull	Peak magnitude: 12000 – 13000 ML/day. Frequency: as in G2 bankfull component. Duration: 2 days. Timing: as in G2 bankfull component Rise and fall: governed by Reach 1 and tributary inputs.	From HEC-RAS model; depth 0.0-0.5 m above bench levels (Vietz et al. 2012). Preference is to coincide (piggy back) with or follow soon after high tributary inflows so that suspended sediment from tributary catchments is dropped onto benches. From HEC-RAS, water velocity > 0.6 m/s requires 10000 ML/day. This is covered by the flow required to maintain benches.
G2, G4, G5 (disruption of river channel armour layer, movement of bed material, scouring of pools,)	Winter-spring bankfull and overbank flows	**Bankfull** Peak magnitude: 14000 ML/day. Frequency: 1 event in 2 out of 3 years, but secondary to other objectives (e.g. wetland inundation). Duration: 1 day at peak flow. Rise and fall: governed by Reach 1 and tributary inputs. **Overbank** Peak magnitude: 20000 ML/day Frequency: 1 every three years in dry and average years, 1 in 2 years wet years Duration: 1 day at peak flow Timing: Any time – can coincide with other requirements such as wetland inundation Rise and fall: governed by Reach 1 and tributary inputs.	Overall, there is very little ability to change bed morphology, except at flows above bankfull up to 20000 ML/day. Shear stress to turn over pebbles (up to 64 mm) in riffles equals 64 Nm^2, from HECRAS model. Modelling indicates that flows greater than bankfull are required for move pebbles – in-channel flows do not have competence to move 100% pebbles. To move 50% of pebbles/cobbles requires bankfull. Bankfull – Rationale for frequency – unimpacted regime gets average of 3 events per year in 96% of years. Get events in most dry years. Overbank – rationale for frequency – unimpacted regime gets 3 events in 80% of years. Adopt 15000 initially to avoid excessive watering, particularly in Reach 2, and measure response before moving to larger events up to 20000 ML/day. Rise and fall – examined current GMW rules and rates proposed by Cottingham et al. (2003); applied a more conservative rate of fall than both sources to account for variability in riparian zone condition and potential for increased rates of bank erosion.

Objectives (habitat feature in parenthesis)	Main Flow Components	Flow Recommendation	Rationale
			To concomitantly reduce sediment smothering from high sediment load tributary inflows, delivery is recommended at end of tributary inflow dominance of flows along the river and just before releases from Lake Eildon start to dominate flows in the river. This timing likely to be winter-spring and can be beneficial for invertebrates and fish also.
NF1 (increased flow variability)	All components	Covered by all previous objectives	As for all previous objectives
NF2, NF4, NF5 (maintain or increase connection to fish habitats)	Winter-spring bankfull, overbank	**Bankfull** Peak magnitude: 14000 ML/day Frequency and timing: Annually preferred, but accept less frequent occurrence to balance with other objectives (e.g. wetland filling only once or drying phase, Macquarie perch breeding). At least 2 events in a year (August and March/April, if not connected earlier in summer) if pursuing this objective. Duration: as for RV 2 (below) Timing: and as in rationale Rise and Fall: governed by Reach 1 and tributary inputs. **Overbank** Peak magnitude: 20000 ML/day Frequency: as for RV2 Duration: as for RV2 Timing: winter-spring, and as in rationale Rise and fall: governed by Reach 1 and tributary inputs.	The intention is to connect the river to anabranches and wetlands at start and end of season the irrigation season to allow fish to move in and out.
RV2, RV3, RV4, RV5, I5, I6 (wetting of riparian zone and wetlands, regeneration of native woody species, entrainment of organic matter)	Winter-spring bankfull and overbank	**Bankfull** Peak magnitude: 14000 ML/day Frequency: Average and wet years: 1 event in 2 years Dry years: 1 event in 3 years in, Maximum interval of 1 in 7 years. Duration: 4 days Timing: winter-spring, and as in rationale. Rise and Fall: governed by Reach 1 and tributary inputs. **Overbank** Peak magnitude: 20000 ML/day	The intent is to increase variability in regulated flows, and meet the needs of native woody species (Roberts and Marston 2011, Greet 2012). The aim is to deliver events of 10000 ML/day and greater, and then draw down to approximately 5000 ML/day, with drawdown before Lake Eildon releases dominate river flows so that flow variability and vegetation diversity are promoted.

Objectives (habitat feature in parenthesis)	Main Flow Components	Flow Recommendation	Rationale
		Frequency: Events up to 15000 ML/day: 1 in 2 years for average and wet years, 1 in 3 years for dry years Events up to 20000 ML/day: 1 in 5 years for average and wet years (not in dry years). Duration: 4 days Timing: winter- early spring, with recession through October Rise and fall: governed by Reach 1 and tributary inputs.	

Appendix 6 Risk matrix

Risk likelihood rating

Almost certain	Is expected to occur in most circumstances
Likely	Will probably occur in most circumstances
Possible	Could occur at some time
Unlikely	Not expected to occur
Rare	May occur in exceptional circumstances only

Risk consequence rating

Critical	Major widespread loss of environmental amenity and progressive irrecoverable environmental damage
Major	Severe loss of environmental amenity and danger of continuing environmental damage
Moderate	Isolated but significant instances of environmental damage that might be reversed with intensive efforts
Minor	Minor instances of environmental damage that could be reversed
Insignificant	No environmental damage

Risk analysis matrix

Likelihood	Consequence				
	Insignificant	Minor	Moderate	Major	Critical
Almost certain	Low	Medium	High	Severe	Severe
Likely	Low	Medium	Medium	High	Severe
Possible	Low	Low	Medium	High	Severe
Unlikely	Low	Low	Low	Medium	High
Rare	Low	Low	Low	Medium	High

Glossary of terms

Alluvium – a general term for sediment deposited in a streambed, on a floodplain or other bottomland feature, delta, or at the base of a mountain during comparatively recent geological time.

Avulsion – the rapid change in the course or position of a stream channel, especially by incision of lowland alluvium, to bypass a meander and thereby shorten channel length and increase channel gradient.

Aggradation – the raising or elevating of a bottomland surface through the process of alluvial deposition.

Bankfull - carrying capacity of the stream before spilling out onto adjacent land.

Baseflow – low flows sufficient to maintain fish passage, water quality, and pool and riffle habitats.

Channel - that part of a river where water flows at some time and includes the bed and banks, taken to mean the whole of the depression in which the water flows before it rises sufficiently to spill over onto adjacent lands as flood water.

Environmental flow regime – the timing, frequency, duration and magnitude of flows for the environment.

Environmental flow study – a scientific study of the flow requirements of a particular basin's river and wetland systems used to inform decisions on the management and allocation of water resources.

Environmental water entitlement – an entitlement to water to achieve environmental objectives in waterways (could be an environmental entitlement, environmental bulk entitlement, water share, *Section 51* license or supply agreement).

Flow - movement downstream of water confined in the channel. The term **lotic** applies to living in flowing or moving water.

Flow component – components of a river system's flow regime such as cease to flow and overbank flows.

Flow regime – a statistical description of flow pattern through time.

Freshes - flows that produce a substantial rise in river height for a short period, but do not overtop the river bank. Freshes help maintain water quality and serve as life cycle cues for fish.

Geomorphology (fluvial) - the physical interaction of flowing water and the natural channels of rivers including erosion and sedimentation.

Gigalitre (GL) – one billion (1,000,000,000) litres or 1,000 megalitres.

High flows - high flow within channel capacity. High flows allow full connection between all habitats in the river.

High reliability entitlement – legally recognised, secure entitlement to a defined share of water, as governed by the reserve policy (full allocations are expected in most years).

Instream - refers to that area of a waterway within the river channel.

Low reliability entitlement – a legally recognised, secure entitlement to a defined share of water, as governed by the reserve policy (full allocations are expected only in some years).

Macroinvertebrates – aquatic invertebrates whose body length usually exceeds 1 mm (such as insects, crustacean, aquatic worms and aquatic snails).

Macrophytes – an aquatic plant that grows in or near water and is either emergent, submergent, or floating.

Megalitre (ML) – one million (1,000,000) litres.

Overbank flow – flows that overtop the banks and spill onto the floodplain.

Passing flow – water released out of storages to operate river and distribution systems (to deliver water to end users), provide for riparian rights and maintain environmental values and other community benefits.

Planktonic algae – floating microscopic plants that are an important food source for aquatic fauna.

Point bar – a depositional feature made of alluvium that accumulates on the convex bend of a migrating stream.

Pool - a significantly deeper area in the bed of a river.

Reach - a length of stream that is reasonably uniform with respect to geomorphology, flow and ecology.

Riffle – a section of the stream with fast and turbulent flow over a pebble bed with protruding rocks (characterised by a broken water surface).

Riparian vegetation - vegetation growing on the river bank or along the very top of the bank that is affected by river flow.

Seasonal allocation – the volume of water allocated to a water share in a given season, expressed as a percentage of total entitlement volume.

Sinuosity - as applied to stream-channel pattern, is a non-dimensional ratio, generally expressed in meters or kilometers, of the length of the channel **thalweg** to the length of the stream valley, measured between the same points.

Unregulated entitlement – an entitlement to water declared during periods of unregulated flow in a river system, that is, flows that are unable to be captured in storages.

Water entitlement – the right to a volume of water that can (usually) be stored in reservoirs and taken and used under specific conditions.

Water Holdings – environmental water entitlements held by the Victorian Environmental Water Holder.

Waterway manager – agency responsible for the environmental management of waterways (includes catchment management authorities and Melbourne Water).

Waterways – can include rivers, wetlands, creeks, floodplains and estuaries.