CORANGAMITE CMA

Moorabool River Environmental Water Management Plan

FINAL *(Version 2.6)*

VICTORIA State Government

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Acknowledgments

Acknowledgement of Country

The Corangamite CMA acknowledges the traditional custodians Wadawurung of the land and waters where we work, and pay our respects to the Elders past and present. The Aboriginal Traditional Owners have existed as part of the land for thousands of generations and have an intrinsic connection to the land, the rivers and the sea. The Corangamite CMA recognises and acknowledges the contribution and interest of Aboriginal people and organisations in waterway and land management.

Contributions to the Moorabool EWMP

The Corangamite Catchment Management Authority would like to acknowledge the input of partner agencies and communities. In particular, the authority would like to acknowledge the contribution of the Moorabool Stakeholder Advisory Committee and the time and expertise committed by individual members.

The Moorabool Stakeholder Advisory Committee in action on the Moorabool River in 2014 (Photo Rachael Roger)

Contents

Executive summary

The Moorabool River Environmental Water Management Plan (EWMP) sets out 5 to 10 year objectives to manage flow-dependent ecological values within reaches 1 to 4 of the Moorabool River, Victoria. A strong emphasis is placed on reaches 3 and 4 (Lal Lal reservoir to confluence with the Barwon River) as this section of river contains the highest ecological values and can be influenced by water held within the Moorabool River Environmental Entitlement 2010.

The EWMP is an important part of the Victorian Environmental Water Planning Framework and is a short to long-term planning tool for managers including, the Corangamite CMA, Victorian Department of Environment, Land, Water and Planning (DELWP), and the Victorian Environmental Water Holder (VEWH). It is not a holistic management plan for the Moorabool River, but rather, concentrates on how environmental water is used to protect ecological values and provide social and cultural outcomes.

The best available scientific information, evidence-based decision-making and stakeholder consultation has been used to develop this document. The EWMP combines the following components to inform management of environmental water and achieve the identified goal.

System hydrology

Prior to European settlement, flows in the Moorabool would have been seasonally variable, with high flows in winter and spring, and low flow in summer and autumn. Currently, harvesting of water in urban storages, farm dams, private diverter usage and groundwater usage significantly impacts the rivers flow regime and the ecological values that depend on the river. In its present state, the Moorabool is one of the most flow stressed rivers in Victoria and only receives 10% of the water required to support these ecological values.

Water-dependent values

The Moorabool River provides a significant biodiversity habitat corridor between the Central Highlands, Victorian Volcanic Plains and through to the Southern Ocean at Barwon Heads. This 200km habitat corridor links the Brisbane Ranges National Park to the Moorabool's local river reserves in the Victorian Volcanic Plain before feeding into the Barwon River reserve and Ramsar-listed Lower Barwon Wetlands. The river sustains life and critical ecological process for many species of native flora and fauna, including fish, macroinvertebrates, mammals (platypus/water rats), birds and Ecological Vegetation Communities. The following long-term goal has been defined for the Moorabool River in partnership with the Moorabool Stakeholder Advisory Committee:

The Environmental Water Management Goal

To improve the Moorabool Rivers flow-dependent ecological values and services through the provision of environmental water. The delivery of environmental water will also provide for social and cultural values for future generations.

(The intent of this goal, developed by the Moorabool Stakeholder Advisory Committee, is to ensure the effective use of the current entitlement and highlight the need for additional water to maintain and improve environmental values.)

Ecological condition and managing threats

The river is in relatively poor condition due to a number of threats affecting its water-dependent ecological values including; flow stress, land clearing and in-stream barriers. This document seeks to manage threats that relate directly to environmental water management. Two fundamental mechanisms are required in order to meet the goal and ecological objectives of this EWMP, they include:

- **Water recovery**
- **Ecological response monitoring**

The ability to meet the EWMP goal and *improve* the Moorabool Rivers flow-dependent ecological values relies on adequate environmental flow volumes. Minimum and aspirational water recovery targets have been developed and scientifically developed through the Moorabool River Flows Study Update (Jacobs, 2015). Monitoring the ecological responses to environmental water delivery provides the mechanism to adapt management of environmental water to achieve the best outcomes.

Water Recovery Targets

The following water recovery targets are required to safeguard the rivers environmental values for conservation and for future generations. These targets have been developed using historical flow data and assume existing bulk entitlements remain as the status quo.

Minimum water recovery target 1

The Minimum Water Recovery Target 1 would enable the delivery of 5,140 ML/year under dry conditions. Importantly, this would require an additional allocation of 2640 ML/year to the existing entitlement, and would require carefully considered changes to the bulk entitlement rules, including alterations to share of storage capacity and inflows. This is a realistic target that has been developed in consideration of the rivers other water resource users and does not provide all of the environmental water needs for the Moorabool. Rather, it would provide the critical minimum environmental water volume to protect the highest priority ecological values.

Minimum water recovery target 2

The Minimum Water Recovery Target 2 would enable the delivery of 9,000 ML/year under wet/average conditions. This would require carefully considered changes to the bulk entitlement rules, including alterations to share of storage capacity and inflows. This target provides the minimum environmental water volume to protect priority ecological values under wet/average conditions.

Aspirational water recovery target 3

The Aspirational Water Recovery Target 3 would enable the delivery of 19,630 ML/year. This target is based on the achievement of all of the recommended flow components (low flows, freshes and high flows) and protection of all of the systems identified ecological values. While it would protect the rivers values, the target is not equivalent to river flows prior to European settlement.

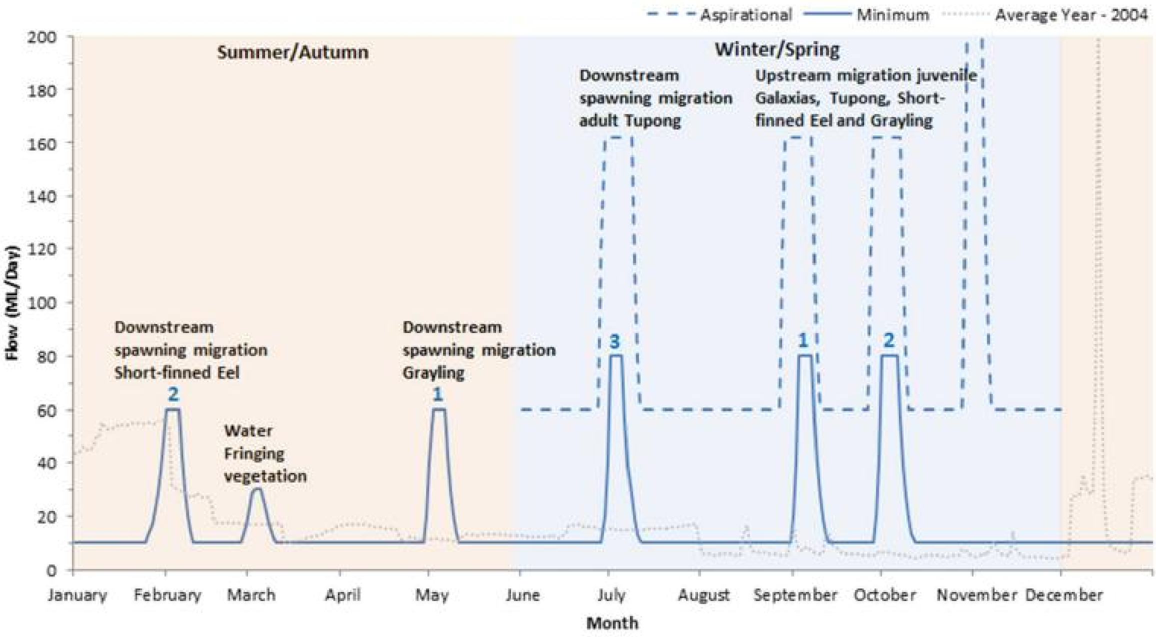
Prioritisation of flows

Flow prioritisation is an important part of flow delivery planning for the Moorabool River due to the limited amount of water available within the environmental entitlement. Prioritisation can help inform (not necessarily determine) water delivery options to achieve the greatest environmental benefit.

The flow priorities for Reaches 3a, 3b and 4 of the Moorabool River are based on the Moorabool River Flows Study Update, and are as follows:

1. **Provision of trigger-based freshes *(drought scenario only)**
2. **Provision of base flows**
3. **Provision of priority 1 freshes**
4. **Provision of priority 2 freshes**
5. **Provision of priority 3 freshes**

The figure below provides a diagrammatic representation of each flow component and the timing of priority freshes 1, 2 and 3. Please note, the recommended volumes of high flow events exceed the capacity of the Lal Lal reservoir outlet and can only be achieved via natural catchment inflows and/or spilling of Lal Lal reservoir. Please refer to *Chapter 6.4.2 Hydrological objectives and flow Recommendations* to see the full list of flow recommendations.



Consultation

Community involvement was crucial in developing the EWMP and associated goals, aspirations and management measures. The Corangamite CMA established a Moorabool Stakeholder Advisory Committee (MSAC) in 2014 that includes community members (People for a Living Moorabool, Landcare), water authorities (Barwon Water, Central Highlands Water) and the Victorian Environmental Water Holder. The MSAC brings together a broad combination of skills and plays an important role in advising the Corangamite CMA on management of environmental water for the Moorabool River, Victoria.

1 Introduction

This Moorabool River Environmental Water Management Plan (EWMP) sets the strategic direction for the environmental watering program over the next 5-10 years to manage flow-dependent values and inform the development of annual Seasonal Watering Proposals. The plan was developed by the Corangamite CMA with the support of the Moorabool Stakeholder Advisory Committee (MSAC) The document also includes an analysis of opportunities and threats to the values of the Moorabool River. More specifically the purpose of this plan is to:

- Set long-term ecological management goal and aspirations
- Define the strategic direction and clear ecological objectives for environmental watering
- Identifies priority management actions, threats, and monitoring requirements
- Provides a 5-10 year planning tool to inform annual Seasonal Watering Proposals

The Corangamite CMA established the Moorabool Stakeholder Advisory Committee (MSAC) in 2014 to support the development of the EWMP and ensure the community had strong involvement and ownership of the goals and objectives. The development of this plan was informed by the Moorabool River Flows Study Update (Jacobs 2015) which provides a scientific basis for watering actions to manage flow-dependent values.

While the Corangamite CMA is the custodian of the Moorabool River EWMP, this document is intended to be used by the community and government partners (Victorian Department of Environment, Land, Water & Planning, Victorian Environmental Water Holder, water authorities) for environmental water planning purposes. The Department of Environment Land Water & Planning provided funding for the EWMP and Moorabool River Flows Study Update.

The Moorabool River has a range of ecologically significant areas the community value, including a regionally significant biodiversity habitat corridor between the Central Highlands (Brisbane Ranges National Park), Victoria's Volcanic Plain and the lower Barwon River and Ramsar-listed wetlands. Local communities and the regional towns of Ballarat and Geelong also have a strong link to the Moorabool River for its social and cultural values. The river is an important waterway for domestic and agricultural water extraction and the lower reach has been identified as part of a Western Growth Area, and will face challenges such as urban development during the next ten years.

The Moorabool River contains a variety of water-dependent ecological values including the iconic platypus, estuarine and freshwater fish species, large tracts of remnant and endangered riparian woodlands, and plains grassland vegetation communities. The river has highly variable natural flows and a diverse range of ecosystems and communities that reflect this variability across river reaches. During periods of drought, deeper habitat pools provide refuge for many fauna and flora species.

The Moorabool River is one of the most flow-stressed rivers in Victoria and its ecological communities will continue to be at risk of decline without water recovery, and appropriate environmental water management activities. This EWMP identifies the need for water recovery and provides the management direction required to maintain and improve the rivers significant ecological values and protect them for future generations.

1.1 Aspirations of the Moorabool Stakeholder Advisory Committee

Representation on the MSAC includes; The Corangamite CMA, Central Highlands Water, adjoining landholders, People for A Living Moorabool, Barwon Water, Landcare, Friends of Buckley's Falls, Victorian Environmental Water Holder, Southern Rural Water and Traditional Owners (seat vacant).

The MSAC is a passionate and dedicated group of people with a broad combination of skills and knowledge including technical knowledge, historical information, government policy, and community values.

The MSAC played an important role in supporting this documents development, including the development of the following environmental water aspirations for the Moorabool River:

Water Recovery

- Increase the Moorabool River Environmental Entitlement 2011 to meet the Minimum Water Recovery Target 1 within 1-4 years. This target allows for the delivery of 5,140ML per year under dry conditions. Any increase in the environmental entitlement may impact on urban water supply and would need to be appropriately assessed.
- Pursue opportunities to secure the Minimum Water Recovery Target 2 within 5-7 years. This target allows for the delivery of 9,000ML per year under wet/average conditions.
- Pursue opportunities to secure the Aspirational Water Recovery Target 3 within 8-10 years. This target allows for the delivery of 19,630ML per year.

River health

- Improved protection of environmental flows and baseflows in river reaches 1 to 4.
- Improvement in ecological health of the 6 ecological objective categories, including fish, platypus, vegetation, macroinvertebrates, geomorphology and water quality (outlined in Table 6.1. Ecological objectives for the Moorabool River system).
- Increased native fish diversity, abundance and habitat ranges within 10 years.

Improved resilience

- Increased coverage of native vegetation through 76 hectares of revegetation and the fenced protection of 86 hectares of the rivers riparian corridor within reaches 3 and 4, consistent with the Regional Waterway Strategy 2014-2022 targets.

2 Site overview

2.1 Site Location

The Moorabool River is located in the north east of the Corangamite CMA region with the Brisbane Ranges National Park and the You Yang's Regional Park to the east and the Leigh and Barwon River catchments to the west. The Moorabool River is the major river system flowing through the Moorabool Basin, stretching approximately 295 km from the central highlands to Fyansford in Geelong where it forms a major tributary of the Barwon River. The Moorabool River provides important flows to the Barwon River and the Ramsar listed Lower Barwon wetland system.

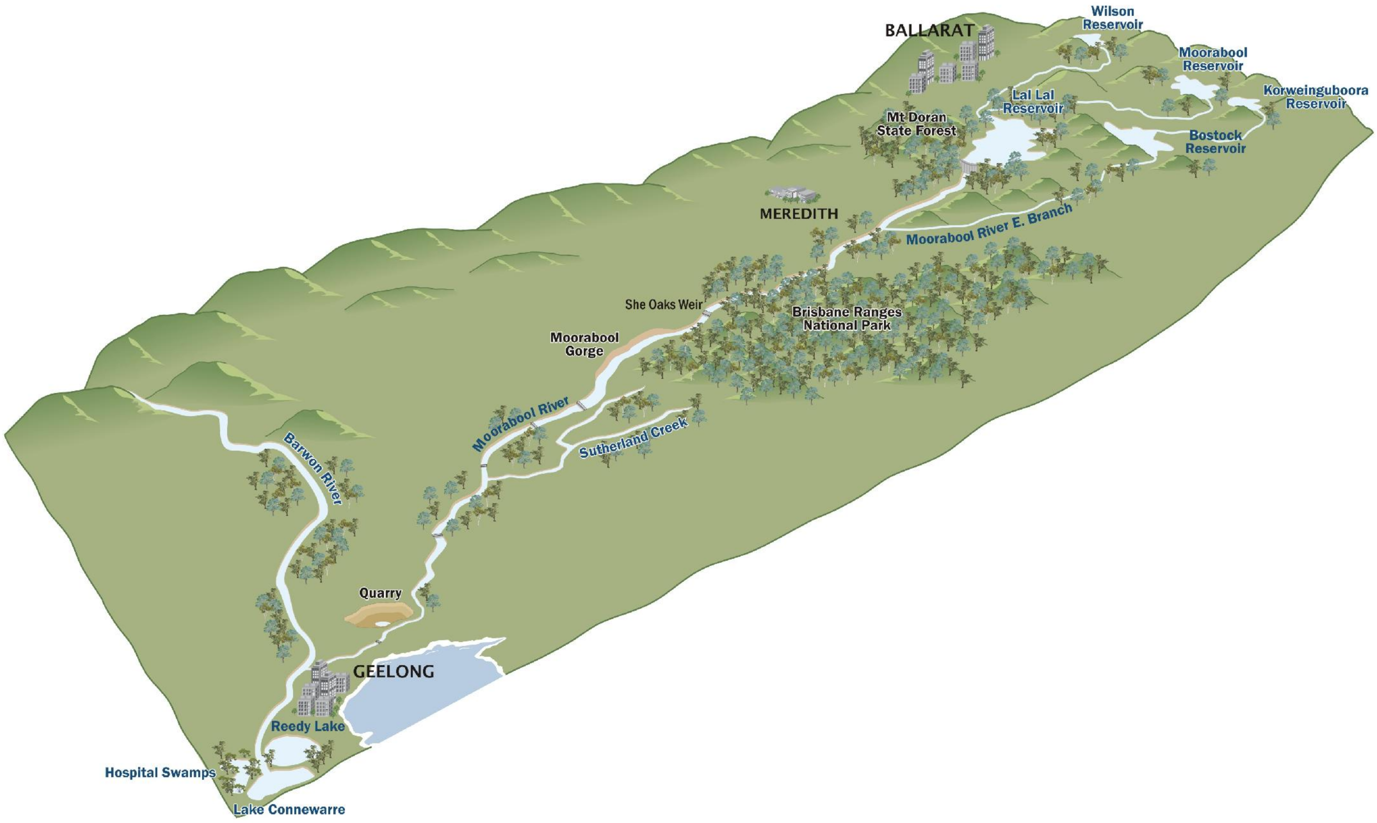


Figure 2: The Moorabool River system

2.2 Catchment Setting

The Moorabool River flows southward from the Central Highlands between Ballarat and Ballan and joins the Barwon River at Fyansford (see Figure 2.1) and is listed as a priority waterway in the Corangamite Waterway Strategy 2014-22 as it is a water supply catchment and has significant environmental and social values.

The Moorabool River Catchment covers an area approximately 1,150 km^2 extending from the Great Dividing Range to the Barwon River. The east and west branches originate in the southern ranges of Wombat State Forest and each branch flows in confined valleys to their confluence just north of Meredith. Below this point, the river continues through a tightly confined valley that broadens downstream to the junction with the Barwon River at Fyansford, near Geelong. The catchment is heavily farmed with about 75 per cent of its area used for agriculture (SKM, 2004b).

Rainfall varies throughout the catchment from 1000 mm in the Central Highlands, located in the north, to 600 mm in the southern catchment in Geelong. Average summer rainfall varies from 140 mm to 105 mm, and average winter rainfall varies from 300 mm to 150 mm. Average annual evaporation is approximately 1100 mm.

2.2.1 Moorabool River water resource operations

The Moorabool River is a regulated river and supplies water for irrigation and urban demands. Since European settlement, the construction of a number of reservoirs and weirs for potable supply and irrigation has substantially reduced flows in the river and reversed seasonal flow patterns. The current flow regime is characterised by longer periods of low flow and shorter periods of high flow.

Farm dams, which capture water before it reaches the river, are having a significant impact on river inflows. The catchment contains more than 4000 dams, with an estimated total storage capacity of 14,400 ML. Modelling indicates that these reduce stream flow by 12,300 ML (Corangamite CMA 2005).

In response to growing demand for potable and irrigated water throughout the greater Geelong and Ballarat regions, a series of reservoirs and water supply infrastructure was installed that had direct impact on the flow and health of the Moorabool River. There are three major storages on the headwaters of the Moorabool River. They are the Moorabool Reservoir (capacity 6,740 ML) and Lal Lal Reservoir (capacity 59,550 ML) on the Moorabool River West Branch and Bostock Reservoir (capacity 7,460 ML) on the Moorabool River East Branch. The smaller Korweinguboora Reservoir (capacity 2,091 ML) is also located on the headwaters of the Moorabool River East Branch (see Figure 2.1).

The catchment is an important source of water for a range of users, including the major urban centres of Geelong and Ballarat, the smaller urban centres of Ballan, Meredith and Bannockburn, stock and domestic water users and irrigators. Water is sourced from both surface and groundwater sources.

A series of weirs are located downstream of Lal Lal Reservoir. The largest weir is She Oaks Weir with a height of 9 m (4-5m barrier above water level). In the lower reach between She Oaks and Batesford there are nine private diversion weirs that are significant barriers to fish. These barriers have increased the extent of slow flowing habitat and reduced habitat diversity in the lower reach of the Moorabool (SKM 2004b).

2.2.2 The Sustainable Diversion Limit

Sinclair Knight Merz carried out a state-wide estimation (SKM, 2002) of the amount of water that can be harvested catchment wide in the winter months (July to October inclusive) that achieves the balance of economic, social and environmental outcomes. This is known at the Sustainable Diversion Limit and provides a conservative estimate of limits to extraction. The Sustainable Diversion Limit for the Moorabool River has been determined to be 3,482 ML/yr (SKM, 2002). Modelling for the 2004 Environmental Flows Study indicates that the average diversion at the time (including the effect of harvesting at storages) over these months was 38,000 ML/yr indicating the system is substantially over developed (SKM, 2004b).

- Sustainable diversion from the Moorabool River is 3,482 ML/yr
- Current diversion from the Moorabool River is 38,000 ML/yr.

2.2.3 River reaches

For planning and ecological management, the Moorabool River is divided into river reaches, with each reach being broadly homogeneous and distinctive in terms of geomorphic and hydrologic features. The FLOWS Study Update (Jacobs, 2015) divided reach 3 into two reaches (3a & 3b) due to the distinct change in hydrological processes.

- Reach 1 - Moorabool River East Branch: Bostock Reservoir to West Moorabool River
- Reach 2 - Moorabool River West Branch: Moorabool Reservoir to Lal Lal Reservoir
- Reach 3a - Moorabool River: Lal Lal Reservoir to confluence with East Branch

- Reach 3b - Moorabool River: Confluence with East Branch to Sharps Road
- Reach 4 - Moorabool River: Sharps Rd to Barwon River.

Reach 1: Moorabool River East Branch: Bostock Reservoir to the confluence with the West Moorabool River

Description – The Moorabool River East Branch downstream of Bostock Reservoir flows through the East Moorabool gorge before reaching a narrow floodplain downstream of Egerton Bungeeltap Road. The valley form alternates between narrow gorges to sections of broad floodplains. Channel contraction is likely to have been a response to flow regulation in this reach, with this leading to encroachment of woody vegetation into the channel and colonisation by emergent macrophytes such as Cumbungi (Craigie et al., 2002). Channel conditions along this reach vary markedly, oscillating between confined gorges sections and unconfined sections with alluvial plains. Deep pools are controlled by bedrock, separated by shallower riffles that have been colonised by emergent macrophytes. The flow regime has been significantly altered due to the impoundment of river flow in Bostock Reservoir, and to a lesser extent, in Korweinguboora Reservoir further upstream. Compared to natural, there has been a decrease in the number and duration of cease to flow events (from 35% to 15%), median flows (from 3.6 to 2.1 ML/day) and an extended low flow period (SKM, 2004b).

Flow Regulators – Korweinguboora Reservoir, Bostock Reservoir, Bolwarra Weir.

On the Moorabool River East Branch, releases from Korweinguboora Reservoir flow eight kilometres down the river to Bolwarra Weir. At Bolwarra Weir, the flow is diverted into the Ballan Channel that carries the water to the Upper Stony Creek Reservoirs. Water from Bostock Reservoir is transferred to the Upper Stony Creek Reservoirs via the 10 kilometre Bostock Channel that connects with the Ballan Channel. Water is supplied by a gravity pipeline from the Upper Stony Creek Reservoirs to Geelong (Montpellier Basins) and Bannockburn district via the She Oaks Weir, Moorabool Water Treatment Plant, and the She Oaks-Montpellier Pipeline.

Reach 2: Moorabool Reservoir to Lal Lal Reservoir

Description – the West Branch forms near Mollongghip before flowing south into the Moorabool Reservoir at Bolwarrah, continuing on to the larger Lal Lal Reservoir formed by Bungal Dam located south of Mt Egerton.

The Moorabool River West Branch between Moorabool and Lal Lal Reservoirs is characterised by a contracted channel that meanders through cleared pastures in the central highlands (SKM, 2004b). The 2004 flow assessment describes the riparian vegetation as being dominated by willows and pasture grasses. Instream vegetation was assessed as being in poor condition, due in part to grazing, stock access and altered flow conditions resulting from the impoundment of Moorabool Reservoir and large number of farm dams located in the upper catchment. Fish in this reach are isolated from the river system due to the presence of barriers upstream (Moorabool Reservoir) and downstream (Lal Lal Reservoir). The flow regime in this reach has been significantly altered. Compared to natural, there has been an increase in cease to flow events and decrease in median flows (from 18 to 2 ML/Day).

Flow Regulators – Moorabool Reservoir.

In the West Moorabool system, flows are diverted from Moorabool Reservoir through a pipeline and open channel system to White Swan Reservoir, the major off stream storage for Ballarat. The channel also collects water released from Wilsons and Beales Reservoirs (1013 ML and 415 ML respectively) which are small storages located in the upper reaches of Lal Lal Creek, a tributary of the Moorabool River West Branch. The pipeline and channel also have the facility to collect flow from a number of watercourses that intersect them. Water from White Swan is treated and supplied to a regional water supply system outside the Moorabool River catchment, known as the Ballarat Water Supply System. This includes Ballarat, Creswick, Ballan, and a large number of small towns up to 50 km from Ballarat.

Reach 3a: Lal Lal Reservoir to Moorabool River East Branch confluence

Description – The Moorabool River West Branch downstream of Lal Lal Reservoir flows through relatively confined gorges to its confluence with Moorabool River East Branch. This reach is significantly impacted by flow regulation, with some reversal of flow seasonality and greatly reduced variability as this reach is used as a conduit for delivering water to She Oaks Weir, which serves as an offtake point for Barwon Water. The river flows through extensive tracts of endangered remnant vegetation that include Stream Bank Shrubland, Riparian Woodland and Grassy Woodland EVCs.

Flow Regulators – Lal Lal Reservoir.

Lal Lal Reservoir is shared by Barwon Water, Central Highlands Water and the Victorian Environmental Water Holder, and is managed by Central Highlands Water. The stored water is shared between the Ballarat Water Supply System, Barwon Water (including Geelong and smaller towns including Meredith, Lethbridge and Bannockburn) and the Environmental Entitlement. The reservoir is managed on a capacity share system in accordance with the entitlements. Central Highlands Water operates a water treatment plant at Lal Lal Reservoir from which treated water is pumped into the Ballarat system to supplement the supply from White Swan Reservoir. A separate supply ispumped from the Moorabool River about 20 km downstream of Lal Lal Reservoir by Barwon Water to the Meredith treatment plant to serve the towns between Meredith and Geelong.

Reach 3b: Moorabool River East Branch confluence to Sharps Rd, She Oaks

Description – Downstream from the confluence of the East and West Branches, the valley form alternates between broad floodplains and confined narrow gorges.

She Oaks Weir forms a major barrier preventing fish movement further upstream into this reach. Live-trapping surveys indicate that platypus were widely distributed along the Moorabool River downstream of Lal Lal Reservoir in the mid-2000s, with up to four individuals captured overnight at a single site (Williams, 2005; Williams & Serena, 2004, 2006). Population size undoubtedly shrunk when flow ceased along much of the Moorabool in the final years of the millennium drought, with the species still likely to be in a post-drought recovery phase.

Flow Regulators –She Oaks Weir.

The confluence of the East and West Moorabool branches is just north of Morrisons. She Oaks Weir is the first major weir below this confluence. Water released from Lal Lal Reservoir is diverted at She Oaks Weir and pumped to the Moorabool water treatment plant. It is then piped 37 km in the She Oaks – Montpellier Transfer Main to the Montpellier service basin. This water is blended with the Barwon Water supply at Montpellier Basins and supplied to customers in Geelong and northern towns such as Lara, Anakie, and Staughton Vale.

Reach 4: Sharps Rd, She Oaks to the confluence with the Barwon River

Description – This reach commences downstream of Sharps Rd, She Oaks and extends to the confluence with the Barwon River. The in-stream and riparian vegetation communities through this reach range from excellent condition at the top of the reach to poor-fair condition at the lower end (SKM, 2004b).

There are several small irrigation weirs along this reach. The weirs create pools upstream, where silt and organic matter accumulate smothering aquatic vegetation and reducing habitat availability. The channel downstream of these weirs appears to have contracted (SKM, 2004a). Further channel adjustments upstream and downstream of the weirs is likely due the presence of these structures and the highly regulated flows in this reach (SKM, 2004a). Downstream of Batesford, the river has been extensively modified through realignment and concrete lining to allow the development of a large limestone quarry (Craigie et al., 2002; SKM, 2004a). A number of small weirs are present downstream of She Oaks that are likely to limit migration of native fish species such as Australian grayling and tupong. The large number of weirs act as a barriers to fish and platypus movement through this reach (SKM, 2004a, 2004b).

Flow Regulators – Batesford Weir and 8 other small private diversion weirs.

Further downstream near Batesford, in 1980, the Batesford Quarry was given approval to mine limestone under the existing course of the Moorabool River at the Batesford Quarry. As a result, a 2.4 km concrete lined diversion channel was installed to re-route the river around the quarry pit and stop water infiltration. Despite these works, water still seeped into the quarry pit which was pumped directly out into Corio Bay (due to high conductivity). In 2011 an agreement was reached that resulted in this water being returned to the Moorabool River approximately 200 metres downstream of the original water course (subject to water quality conditions in the discharge licence).

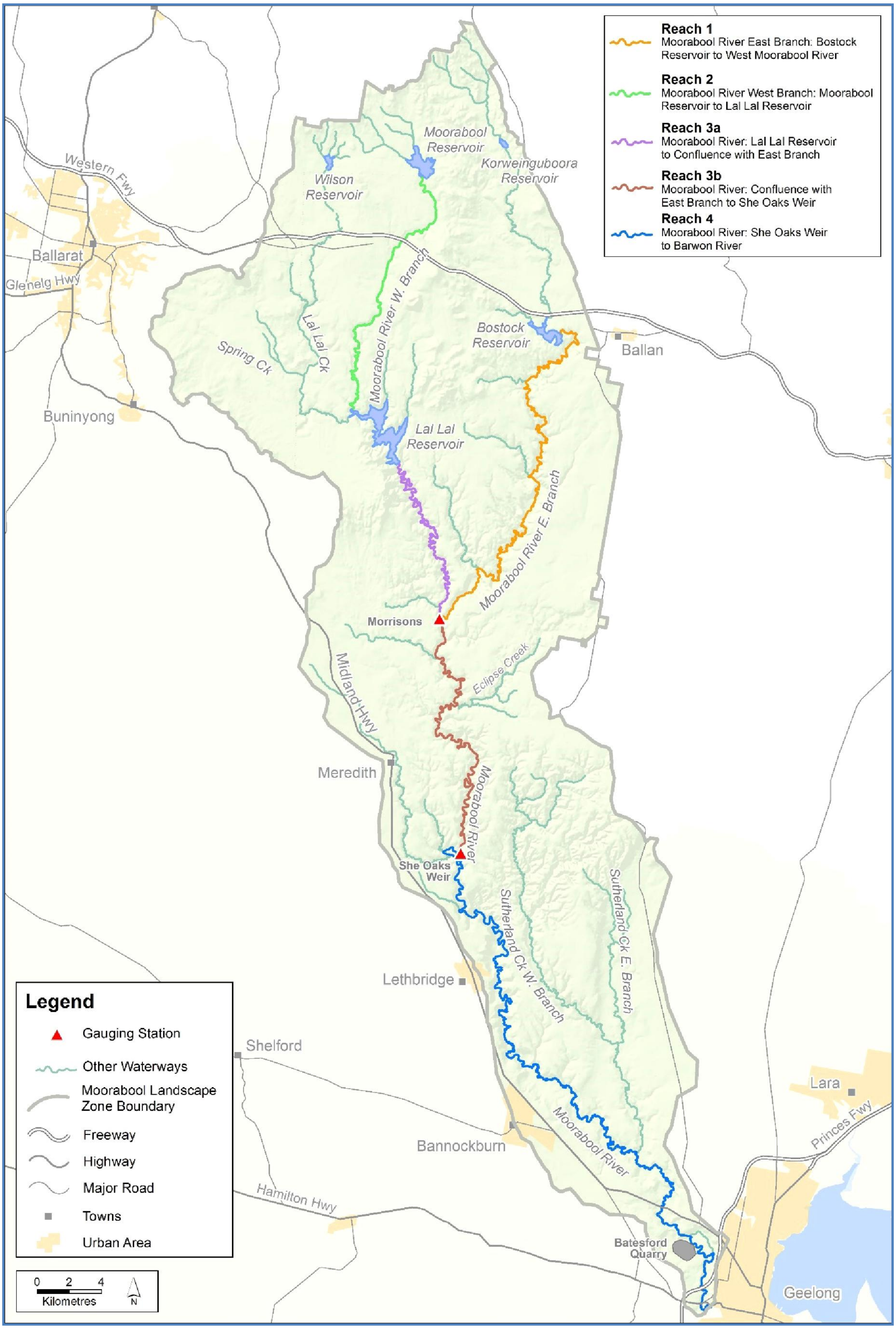


Figure 2.1: The Moorabool River, separated into reaches

2.3 Land status and management

The Moorabool River flows through rural, urban, and peri-urban townships. Reaches 3a, 3b and 4 pass through the districts of She Oaks and Russell's Bridge and the townships of Maude, Bannockburn, Batesford and Geelong. A significant length of the land adjoining the Moorabool River is privately owned and restricting stock access to the river and the riparian frontage is a challenge, particularly when a large proportion of the frontage remains unfenced. A small percentage (approximately 15 per cent) is protected through reserves, parks and unleased crown land, however, estimates of overall river length protected by intact fencing are as low as 20 per cent (CCMA, 2015).

2.3.1 Environmental water management

A number of agencies are directly involved in environmental water management in Victoria. Other agencies, such as public land managers, have an important role in facilitating the delivery of environmental water. In addition, multiple organisations and groups provide input and advice on the best use of environmental water in the Moorabool River system. All water users have a responsibility to ensure the sustainable use of water, whether its water for the environment or consumptive use, as outlined in Table 2.1.

Table 2.1. Roles and responsibilities for environmental water management in the Moorabool River system (DEPI, 2013a and VEWH, 2014)

Agency/group	Responsibilities/involvement
Groups/committees involved in environmental watering of the Moorabool River	
Moorabool Stakeholder Advisory Committee **(MSAC)**	The Moorabool Stakeholder Advisory Committee was established to support the development of the EWMP and provide advice to the Corangamite CMA on the use of environmental water for the Moorabool River. Stakeholders represented on MSAC include Corangamite CMA, Central Highlands Water, adjoining landholders, People for A Living Moorabool, Barwon Water, Landcare, Friends of Buckley's Falls, Victorian Environmental Water Holder, Southern Rural Water and Traditional Owners (seat vacant).
People for a Living Moorabool (PALM)	PALM is a local community group who advocate for a healthier Moorabool River system and provide advice and support to the Corangamite CMA on the use of environmental water for the Moorabool River.
Traditional Owners / Aboriginal Groups	The delivery of environmental water is likely to provide other benefits that depend on the condition of our waterways, such as enhancing cultural values.
Geelong Landcare (GL)	Regional Landcare group that takes an active role in land management and conservation along the Moorabool River.
FLOWS Scientific Advisory Committee	Established to support the development of the FLOWS Study and provide independent advice to the Corangamite CMA on the use of environmental water to support the five ecological value categories.
Government organisations and agencies	
Corangamite Catchment Authority (Corangamite CMA) *– Waterway Manager*	• Identifies regional priorities for environmental water management in the Corangamite Waterway Strategy. • In consultation with the community, identify water regime requirements of priority rivers and wetlands to meet agreed management objectives. • In consultation with the community, identify opportunities for, and implement, environmental works to use environmental water more

Agency/group	Responsibilities/involvement
	efficiently. • In consultation with the community, propose annual environmental watering actions to the VEWH and implement priority actions in the Seasonal Watering Plan. • Provide critical input to management of other types of environmental water (passing flows management, above cap water) and report on environmental water management activities undertaken.
Victorian Environmental Water Holder (VEWH)	• Make decisions about the most effective use of the 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. • Publicly communicate environmental watering decisions and outcomes.
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 VEWH and waterway managers (in their role as environmental water managers).
Water Corporations – Central Highlands Water, Barwon Water and Southern Rural Water *-Storage Manager and Resource Manager*	• Work with the VEWH 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. • Ensure the provision of passing flows and compliance with management of diversion limits in unregulated and groundwater systems.

2.4 Management scale and environmental water sources

Table 2.2 provides a summary of the water sources available for each of the five Moorabool River reaches (see Section 2.2.2 for reach descriptions). The table includes Barwon Water's consumptive releases from Lal Lal Reservoir, which are not for environmental watering purposes, but transfer flows contribute to achieving the ecological objectives defined for reaches 3a and 3b.

Table 2.2. Summary of water sources available to the Moorabool River system and responsible agencies

Available water	Volume (ML)	Responsible Agency	Affected reach
Water Entitlements			
Moorabool River Environmental Entitlement	Storage capacity of 7,086 ML (a maximum use of 7,500 ML over three years)	Victorian Environmental Water Holder	3a, 3b, 4
Bulk Entitlement (Lal Lal Reservoir)	Water is available to the environment under the bulk entitlement as passing flows. For Lal Lal Reservoir, passing flow requirements are 5 ML/day (or calculated inflows into the reservoir) when inflow has been less than 43 GL over 2 years, or 20 ML/day (or calculated inflows into the reservoir) when inflow has been greater than 43 GL for 2 years.	Central Highlands Water	3a, 3b, 4
Bulk Entitlement (Moorabool Reservoir)	Water is available to the environment under the bulk entitlement as passing flows. For the Moorabool Reservoir, passing flow requirements are the lesser of 3 ML/day or gauged inflows into the reservoir.	Central Highlands Water	2
Bulk Entitlement (Bostock Reservoir)	Water is available to the environment under the bulk entitlement as passing flows. For the Bostock Reservoir, passing flow requirements are the lesser of flow into the reservoir and 1.2 ML/day from December to July and 0.8 ML/day August to November.	Barwon Water	1
Other water sources			
Barwon Water consumptive releases	Water is released for use in Geelong's water supply from Lal Lal Reservoir and extracted from Barwon Water's offtake at She Oaks weir. Timing and quantity of releases varies based on consumptive demand and rainfall. This water plays a critical role in providing summer baseflow which is the highest priority flow component for the Moorabool River.	Barwon Water	3a, 3b
Batesford Quarry dewatering discharge	~3,000 ML per year is discharged from Batesford Quarry dewatering back into the Moorabool River north of the quarry.	Adelaide Brighton Ltd Pty	4

2.6 Related agreements, policy, plans and activities

There are a number of policies, strategies, plans and activities that are relevant to environmental water management of the Moorabool River system. Relevant state, national and international legislation, policy and agreements include:

State legislation:

- Water Act 1989
- Catchment and Land Protection (CaLP) Act 1994
- Flora and Fauna Guarantee (FFG) Act 1988
- Aboriginal Heritage Act 2006
- Traditional Owner Settlement Act 2010
- Conservation, Forests and Lands Act 1987
- Crown Land (Reserves) Act 1978.

Federal legislation:

- Water Act 2007 and Water Amendment Act 2008
- Environment Protection and Biodiversity Conservation (EPBC) Act 1999
- Native Title Act 1993
- The Convention on Conservation of Migratory Species of Wild Animals
- Japan-Australia Migratory Bird Agreement (JAMBA)
- China-Australia Migratory Bird Agreement (CAMBA)
- Republic of Korea- Australia Migratory Bird Agreement (ROKAMBA).

Strategies and projects:

- Victorian Waterway Management Strategy 2013 (VWMS) – this strategy details the framework for government, in partnership with the community, to maintain or improve the condition of rivers, estuaries and wetlands so that they can continue to provide environmental, social, cultural and economic values for all Victorians. The framework is based on regional planning processes and decision-making, within the broader system of integrated catchment management in Victoria (DEPI 2013).
- Sustainable Water Strategy – Central region' (DSE, 2006)
- 2014-2022 - Corangamite Waterway Strategy – this regional strategy is an action out of the VWMS and provides the framework for managing rivers and wetlands with the community over the next eight years. It delivers key elements of the VWMS including developing work programs to maintain or improve the environmental condition of waterways in the Corangamite region.
- Living Ballarat Strategy –DELWP. Strategy defines water augmentation options to create a more sustainable and environmentally sustainable community. This document identifies policy objectives (initiative 3.5.1, 3.5.3 & 3.7.1) that, if implemented, may return environmental water to the Moorabool River. This document demonstrates how environmental watering outcomes may be achieved through water augmentation in the Moorabool catchment.

2.7 Environmental watering

The Moorabool River Environmental Entitlement was established in 2010 and is held In Lal Lal Reservoir. This entitlement enables up to 7086 ML to be stored in Lal Lal Reservoir and is subject to delivery rules (a maximum use of 7500 ML over three years) which provides the environment with an average of 2500 ML per year. Additional options to environmental water are available to achieve environmental outcomes, including passing flows and the Barwon Water Bulk Entitlement releases from Lal Lal reservoir. The Corangamite CMA and Barwon Water discuss water delivery plans each year to ensure water releases from Lal Lal achieve mutually beneficial outcomes for the environment and potable water supply.

Passing flows from Lal Lal Reservoir are also a significant component of annual stream flow below this structure and are important in maintaining base flows through winter. Holders of bulk entitlements must allow a portion of inflow into Lal Lal Reservoir to continue into the river below the dam. Passing flow rules stipulate release of 5 ML/Day (or calculated inflows into the reservoir) when inflow has been less than 43 GL over 2 years, or 20 ML/Day (or calculated inflows into the reservoir) when inflow has been over 43 GL for 2 years. Passing flows from Lal Lal Reservoir are currently at 5 ML/day or calculated inflows into the reservoir (whichever is lesser). Passing flows do not affect the volume of water allocated to the environmental entitlement, nor do they restrict the ability to use the Moorabool River Environmental Entitlement. Passing flows are an important source of water for the Moorabool River and where opportunity exists, the environmental water is used to in conjunction with these flows to achieve greater outcomes. In addition to passing flows, Barwon Water and the Corangamite CMA.

Between 1997 and 2009 south-eastern Australia experienced the worst drought on instrumental record. The prolonged drought conditions resulted in a qualification of rights for critical human supply in November 2006. This cut passing flow requirements leading to a series of prolonged cease to flow events. The river was reduced to a series of isolated pools significantly reducing the recruitment of native fish and reducing the habitat available for platypus and other aquatic species dependent on the Moorabool River (McGuckin 2008).

No environmental entitlement exists for Bostock or Moorabool reservoirs, however passing flow rules are in place for these reservoirs for Reaches 1 and 2. The passing flow requirements for Moorabool Reservoir are the lesser of 3 ML/Day or gauged inflows into the reservoir. For Bostock Reservoir it is the lesser of flow into the reservoir and 1.2 ML/Day from December to July and 0.8 ML/day August to November. The passing flow requirements are less than the existing recommended minimum environmental flows for these reaches (SKM 2004b).

Figure 2.2 presents average daily flows for Morrisons Gauging Station for the period 2002 to 2015 against the recommended flows for Reach 3 from the 2015 Moorabool River Environmental FLOWS Study. Table 2.3 provides an assessment of the compliance of flows delivered during this period, with the environmental flow recommendations. In the majority of cases, recommended flow components required to achieve the ecological objectives for the Moorabool River were not met.

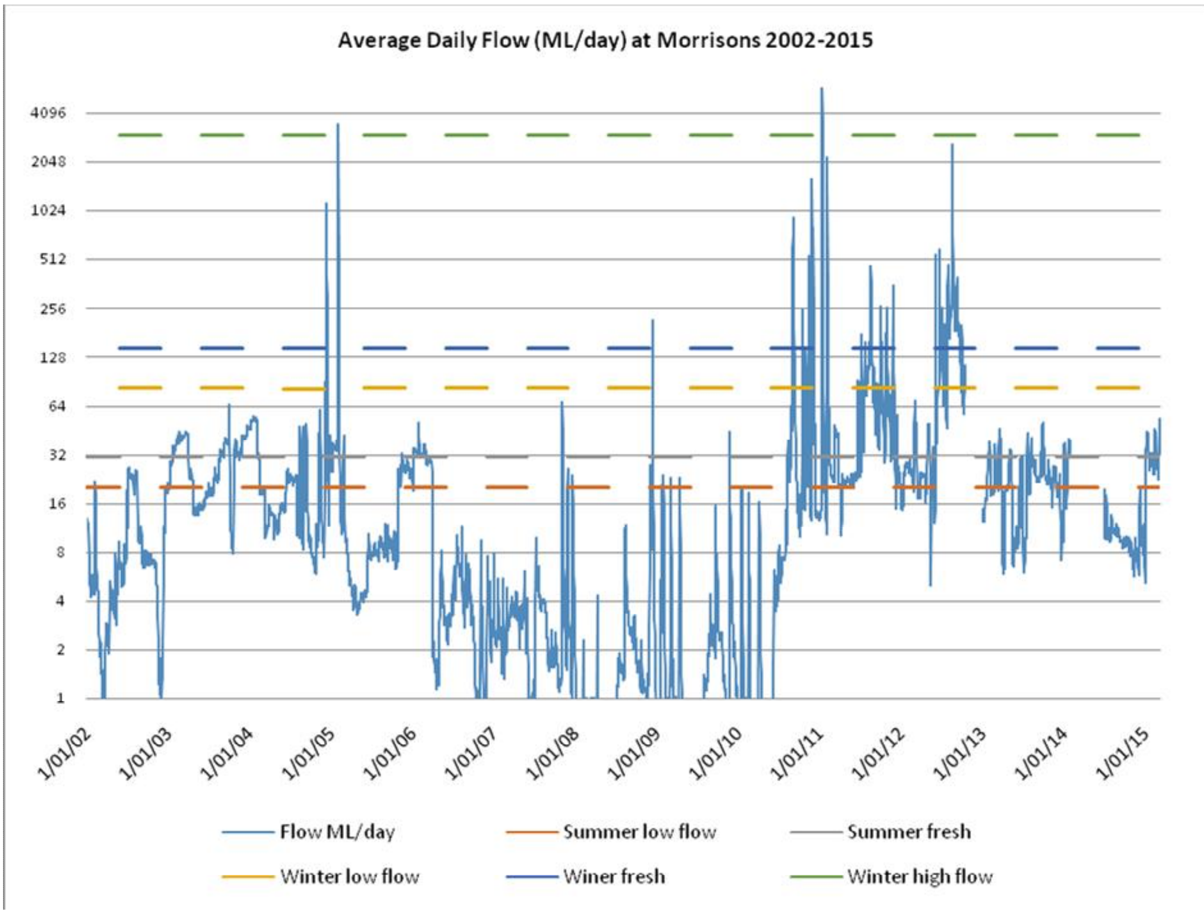


Figure 2.2. Average daily flow (ML/Day) at Morrisons Stream Gauge (upstream end of Reach 3b) for the period 2002-2015 showing recommended flows.

Since the 2010-11 water year (the first year of the environmental entitlement), environmental flows from Lal Lal Reservoir have predominantly been released during the summer period. This is because summer is the critical water quality risk period for flow-dependant biota. The total volume of water available within the entitlement is limited and the larger magnitude of water required to achieve winter flow recommendations, combined with delivery constraints at Lal Lal Reservoir (approximately 146 ML/Day) makes it very difficult to achieve winter flow components. Barwon Water Bulk Entitlement releases in reaches 3a and 3b during Summer has also contributed to a reversal in flow seasonality in the river, particularly in dry to average years where summer environmental flow components are prioritised over winter flow components to ensure ecological objectives can also be achieved in reach 4. Table 2.3 highlights water years where summer flow components were achieved and winter component were not achieved.

Table 2.3. Provision of environmental flow recommendations measured at Morrisons Gauging Station 2001 – 2015.

Flow component		Hydrological achievement of flow components over time															Ecological outcomes/observations
		2001	2002	2003	2004	2005	2006	2007	2008	2009	2010 – 11	2011 – 12	2012 – 13	2013 – 14	2014 – 15	2015 - 16	
Summer	Low flow	Red	Amber	Amber	Red	Amber	Red	Red	Red	Red	Amber	Green	Green	Green	Green	Red	E, O
	Freshes	Red	Green	Green	Green	Amber	Red	Red	Red	Red	Green	Green	Green	Green	Green	Red	E
Winter	Low flow	Red	Red	Red	Red	Red	Red	Red	Red	Red	Green	Amber	Green	Red	Red	Red	E, U
	Freshes	Red	Red	Red	Red	Red	Red	Green	Red	Red	Amber	Green	Green	Amber	Amber	Red	E
	High flow	Red	Red	Red	Green	Red	Red	Red	Red	Red	Green	Red	Amber	Red	Red	Red	U

Key	
Red	No significant part of the flow component achieved
Amber	Flow component partially achieved
Green	Flow component has been completely achieved, i.e., duration, frequency and volume was achieved

3 Hydrology and system operations

3.1 River Hydrology

The following descriptions of natural and historic flows are based on information in the 2004 Environmental Flows study (SKM 2004b) and the 2015 Environmental Flows Study Update (Jacobs, 2015).

Prior to European settlement, flows would have been seasonally variable, with high flows in winter and spring, and low or no flow in summer and autumn. Currently, the flow regime is significantly impacted by impoundments and diversions, by run-off interception in farm dams, private diverter usage and groundwater usage. The cumulative effect of these impacts is apparent when comparing historic and natural flows that have been derived for FLOWS assessment sites in the Moorabool Catchment (Figure 3.1). Reaches 3a and 3b immediately downstream of Lal Lal Reservoir experiences an artificial flow regime (high flows in summer) and decreased hydrological variability due to its use to transfer water from Lal Lal Reservoir to She Oaks.

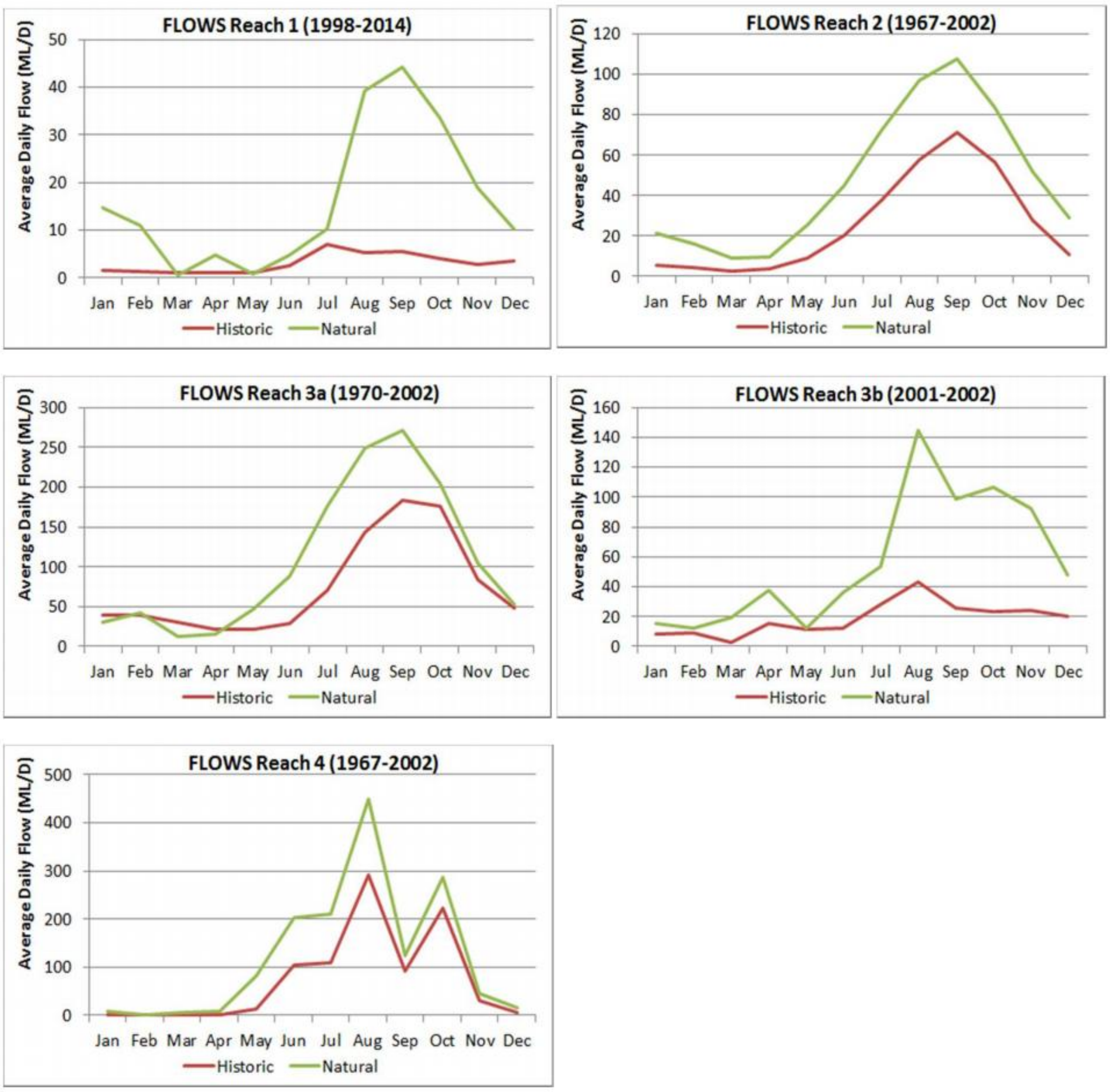


Figure 3.1. Average historic and natural flow volumes for FLOWS Assessment sites in the Moorabool Catchment (Jacobs, 2015).

Farm dams, which capture water before it reaches the river, are having a significant impact on river inflows. The catchment contains more than 4000 dams, with an estimated total storage capacity of 14,400 ML. Modelling of farm dams indicates that the collection of water in farm dams results in a reduction in stream flow of 12,300 ML (Corangamite CMA 2005).

3.2 Groundwater and surface water interactions

This description of groundwater and surface water interactions is based on the 2004 FLOWS assessment (SKM, 2004b) and on more recent investigations in the catchment (Horgan 2006, Evans 2006, Harbour 2012). It is recognized that there are strong surface and groundwater relationships in the Moorabool River although very little is known regarding this relationship across the catchment. Despite this, groundwater gains and losses appear to represent a significant component of the water balance at many locations, including Bungal and Batesford (S Vermeeren pers comm, 2015), which is consistent with the findings of Horgan (2006) detailed below.

Harbour (2012) conceptualised baseflow to the Moorabool River East Branch (Reach 1) to come from the newer volcanic basalt and the upper and lower tertiary aquifers. During drier periods the baseflow from the basement aquifer may also contribute to streamflow. Under regulated conditions, this baseflow could potentially sustain flow in the river all year around in this part of the catchment. Harbour (2012) estimate baseflow contribution of between 30% and 50%, although there is not enough gauge information at She Oaks (??) weir to quantify the estimates. Nevertheless, this more recent work provides further supporting evidence that groundwater discharge is an important component of baseflow in Reach 1 of the Moorabool River.

Evans (2006) undertook a study of the geology and groundwater flow systems in the West Moorabool River catchment and their relation to river salinity, and noted that compared to the level of knowledge available for surface water, the groundwater contribution to river flow is poorly understood. Evans (2006) did note that water table elevation contours and electrical conductivity patterns suggest that groundwater does flow to and discharge into parts of the Moorabool River West Branch. SKM (2004b) estimated baseflow contribution in the upper catchment (upstream of Moorabool River), to range from 50% to 60% and in the middle catchment (upstream of Lal Lal Reservoir, ie Reach 2) between 30% to 40%. No more recent information is available regarding baseflow contributions in the Moorabool River West Branch.

Horgan (2006) studied the hydrogeology of the Morrisons-She Oaks Area, which corresponds with sections of the Moorabool River downstream of Lal Lal Reservoir (Reaches 3a, 3b and 4), and found that stream flow data and groundwater level monitoring were largely non-existent or of insufficient quality to produce a meaningful interpretations of the groundwater – surface water interactions.

Table 3.1 summarises current understanding of groundwater and surface water interactions along the Moorabool River downstream of Lal Lal Reservoir as it relates to the different hydrogeological units. In contrast to the upper catchment, the general indications are that the baseflow contribution to the streamflow from the Newer Volcanics, Quaternary Deposits and Highland Gravel Caps are lower and groundwater discharge from the Palaeozoic Basement Rocks is greater than previously thought. The reduction in average stream flows at Morrisons and Batesford and respective corresponding increases in electrical conductivity has been attributed to an increasing portion of streamflow being derived from baseflow contributions, throughout a period of below average rainfall.

Table 3.1. Summary of groundwater surface and water interactions for the Moorabool River, downstream of Lal Lal Reservoir (Horgan 2006).

Hydrogeological unit	Summary of findings on groundwater surface water interactions
Newer Volcanics	Not considered to contribute significant base flow to the Moorabool River. Thought to be little connectivity between newer volcanics in the northern upper catchment with those in the southern catchment.
Quaternary Deposits	Shallow alluvial aquifers are not likely to provide significant baseflow to streams, based on the observation that discharge sites that were observed after above average rainfall, ceased discharge after a period of below average rainfall. It is more likely that the alluvial aquifers allow excess water to move through them as through flow after high rainfall periods
Highland Gravel Caps	The initial groundwater conceptual model created for this area involved saline discharge from the Tertiary highland gravel caps to the Moorabool River. This hypothesis was deemed largely incorrect (or not a significant process in the catchment) given the caps are locally thin and do not contain a permanent watertable.
Palaeozoic Basement Rocks	Major drainage lines incise the Palaeozoic basement rocks and form discharge zones for groundwater flow to the Moorabool River. Greater hydraulic conductivities have been measured than those previously estimated, meaning there is a potential that baseflow and salt wash off from discharge areas may be significant and therefore potentially provides more salt to the Moorabool River and its tributaries than expected.

3.2.1 Batesford quarry –groundwater interactions

The Batesford quarry is adjacent to the Moorabool River, three kilometres downstream of Batesford Weir (Figure 2.1) (Figures 3.2 and 3.3). At this point a proportion of river flow seeps into groundwater sinkholes and into the Batesford quarry. Since 2011, water has been pumped from Batesford quarry back into the Moorabool River, 1-2 km downstream of the sinkholes, which means this 1-2 km reach of river is devoid of water for extended periods. This impacts on aquatic values and acts as a barrier to fish movement.

This can be avoided, by releasing flows from Lal Lal Reservoir (>30ML day) to provide connectivity through this section of reach 4 (S. Vermeeren Pers. Comm) (Figure 3.3). Once this section of river is reconnected with flows it enables fish passage from the Moorabool River into the ocean at Barwon Heads, via the Barwon River.

Figure 3.2. Collapsed concrete lining on the Moorabool River undertaken in the 1980s to stop groundwater intrusion into the quarry pit. Photo taken prior to 2014 summer fresh (Photo: Saul. Vermeeren 2014)

Figure 3.3. A large pool on the Moorabool River, downstream of figure 3.2, following a 2014 summer fresh flow to reconnect 2kms of river between the Batesford Quarry and the Barwon River (Photo: Saul. Vermeeren 2014).

4 Water dependent values

The focus of this document is to determine how water-dependent environmental values will be managed over a 10-year period with the use of the environmental water. The water-dependent environmental values of the Moorabool River have been identified using a variety of inputs, including flows studies, scientific surveys, the Corangamite Waterway Strategy, Victorian Waterway Management Strategy and consultation with various groups including the Moorabool Stakeholder Advisory Committee and the FLOWS Scientific Advisory Panel. Environmental water also provides benefits to recreation, tourism, cultural heritage, and regional values.

4.1 Environmental values

4.1.1 Fish

The health of a fish population can be assessed by diversity, abundance, distribution, size class and ratio of native and introduced fish species. For example, losses result in a form of imbalance, and the effects are compounded when these are replaced by alien species. An unhealthy population is one substantially changed from its natural state that may have lost native and gained alien species. The Moorabool River fish population has been impacted by barriers to fish movement, changed habitat conditions and altered flow regimes which have transformed the structure of the fish community (ARI, 2015). However, rehabilitation actions including the installation of fishways (e.g. lower Barwon breakwater), riparian improvement works and utilisation of environmental water are useful tools that are improving the health of the Moorabool River fish population.

2014 Fish Survey in the Moorabool

In 2014, fish surveys were completed at 21 sites in reach 3a, 3b and 4, to determine the current condition of fish populations and evaluate the effectiveness of the environmental watering program since it started in 2010. The key findings of the study included:

- There is a continued need for environmental flows (e.g. spring 'freshes') to encourage and promote movement of fish into and throughout the Moorabool River (ARI 2015).
- Environmental flow releases in 2013 and 2014 provided through the environmental entitlement have increased river heights and flooded weirs in Reach 4 and have provided connectivity and recruitment in this reach (ARI 2015).
- The ecological health of the Moorabool River system (as determined by fish diversity, abundance, distribution, size class and ratio of native and introduced fish species) improved from 2008 to 2014 (ARI 2015).
- There has been a decline in the abundance and distribution of the introduced Eastern gambusia, that may be associated with high flows from floods and additional water from environmental flows (ARI 2015).
- The fish community in the reach 4 (lower reach) closely resembles that which is expected. Diadromous species are, however, largely absent from reach 3a and 3b (middle and upper reaches). This is likely a result of poor fish passage as a result of physical barriers in Reach 4. This will need to be addressed before diadromous species can extend to these reaches. Environmental flows have improved passage over smaller structures that are present in these lower reaches (ARI 2015).
- The nationally threatened Australian grayling was not recorded in the 2014 surveys. Recent monitoring indicates however they are present in the Barwon River. Their absence from the lower Moorabool River is likely associated with impaired fish passage and unsuitable water quality, including high turbidity and temperature and low DO (ARI 2015).

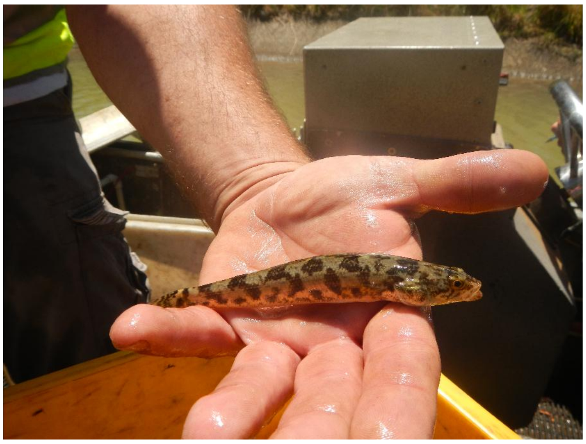


Figure 4.1: **Left**: Tupong, a migratory native species caught near Batesford; **Right**: ARI aquatic sampling in 2014 (Photos: Saul. Vermeeren 2014).

Surveys have recorded 15 native freshwater fish species in Moorabool River system (Table 4.1). Fish species richness (diversity) is higher in Reach 4 than Reaches 1 and 3. Species richness within Reach 4 was greatest downstream of Batesford Weir. The hydrodynamic diversity below Batesford Weir provides a combination of lotic and lentic habitats capable of supporting a variety of species with preferences for different flows and habitat types (ARI, 2015). Blue-spot goby, which predominantly inhabit estuarine waters, have also occasionally been recorded in Reach 4. A summary of the fish species and their conservation status is provided below.

Table 4.1. Fish species recorded in the Moorabool River system

Scientific name	Common name	Conservation status	Collected in 2014	Reach occupied
Migratory species				
Anguilla australis	Short-finned eel	Common	√	1, 2, 3a, 3b, 4
Galaxias brevipinnis	Climbing galaxias	Common	x	-
Galaxias maculatus	Common galaxias	Common	√	4
Pseudaphritisurvillii	Tupong	Common	√	4
Prototroctesmaraena	Australian grayling	Vulnerable (EPBC, IUCN) Threatened (FFG)	x	4
Galaxias truttaceus	Spotted galaxias	Common	√	4
Mordaciamordax	Short-headed lamprey	Common	x	-
Non-migratory species				
Pseudogobius sp.	Blue-spotted gudgeon	Common	x	-
Philypnodongrandiceps	Flat-headed gudgeon	Common	√	1, 3a, 3b, 4
Retropinnasemoni	Australian smelt	Common	√	3b, 4
Gadopsismarmoratus	River blackfish	Common	√	1, 3a, 3b, 4
Nannopercaaustralis	Southern pygmy perch	Common	√	4

Galaxias olidus	Mountain galaxias	Common	x	-
Geotriaaustralis	Pouched lamprey	Common	x	-
Exotic				
Cyprinuscarpio	Common carp	Common	√	3b, 4
Gambusiaholbrooki	Eastern Gambusia	Common	√	1, 3b, 4
Percafluvialtilis	Redfin	Common	√	1, 3b, 4
Salmo trutta	Brown trout	Common	√	3a, 3b, 4
Tincatinca	Tench	Common	√	1, 3b, 4
Rutilusrutilus	Roach	Common	x	-

Six of the native freshwater fish species exhibit obligatory diadromous life histories i.e. move between freshwater and marine habitats at some stage during their life cycle (Harris, 1984). Of the diadromous species in the Moorabool River, three are catadromous i.e. enter rivers from the sea as juveniles, and adults return to the sea or estuary to spawn (tupong, short-finned eel, common galaxias), two are amphidromous (i.e. mature and spawn in fresh water and the larvae drift downstream to the sea, with juveniles migrating back into fresh water) (Australian grayling, spotted galaxias) and one is anadromous (i.e. enter rivers from the sea as mature adults and migrate to upstream spawning grounds, with juveniles later migrating downstream to the sea) (short-headed lamprey). Australian grayling has declined dramatically since European settlement and is currently listed as vulnerable under the IUCN Red List of Threatened Species and EPBC Act as well as threatened under the FFG Act. Altered flow regimes, barriers to movement, habitat degradation and alien species are considered likely contributors to the decline (Backhouse et al. 2008b).

Diadromous species in the Moorabool River are more prevalent Reach 4 below Batesford Weir, an exception is short-finned eel, which are capable of climbing over barriers. One of the most significant findings of the 2014 surveys was collections of low numbers of spotted galaxias, common galaxias and tupong upstream of Batesford Weir. This is attributed to environmental flow releases in 2013 and 2014 which increased river heights and flooded weirs in Reach 4 at critical times of the year, and so provided connectivity and recruitment in this reach (ARI 2015). The collection of short lived diadromous fish species such as the common galaxias, which lives for only 3 years (Pollard 1971) indicates that fish successfully moved upstream in response to provision of freshes: four freshes (> 30ML/d) were provided between January and July 2013 and the large (>65ML/d) winter fresh in 2014.

Five of the native freshwater species in the Moorabool River system are ‘non-migratory’, although one species, Australian smelt, may have both diadromous and non-diadromous characteristics (Crook et al. 2008). Mountain galaxias reportedly had a previously limited distribution restricted to the reaches 3a and 3b, but was not recorded in recent surveys. Little detailed information is provided on flat-headed gudgeon in the previous flows assessment, but recent surveys indicate that this species is widely distributed. This species generally tolerates a wide range of environmental conditions and flow regulation is unlikely to have a major adverse effect on them (Balcombe et al. 2011; Humphries et al. 2012). River blackfish and southern pygmy perch reported previously had a wide distribution that extends from the junction with the Barwon River to the junction with Coolebarghurk Creek near Meredith, although recent surveys indicate that the former species is also found further upstream including in the East and West branches.

Six introduced fish species have been recorded in the Moorabool River system. Three species, eastern gambusia, carp and goldfish, were not recorded prior to the 2015 survey by ARI (Raymond, 2015). Four of the six exotic species (brown trout, tench, Eastern gambusia and redfin perch) showed evidence of recent recruitment while goldfish and common carp did not. Recent surveys indicate that Eastern gambusia are widespread. This introduced species is a highly successful invader of aquatic environments, thought to detrimentally impact native fishes directly (Macdonald et al. 2012).

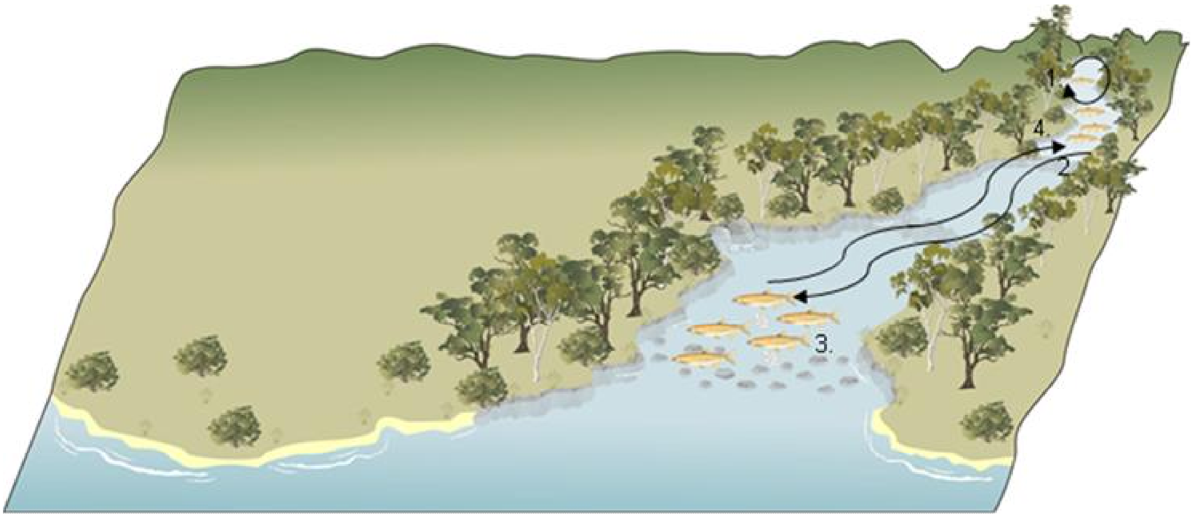


Figure 4.2: Summary of movement behaviours of adult Australian grayling and links to flow. (Jacobs, 2015)

Figure 4.2 represents migratory movement for Australian grayling between rivers and oceans. In explanation:

1. Fish display only small-scale movement prior to migrating downstream.
2. Fish undertake rapid long-distance downstream migrations to the lower reaches of rivers in April–May, coinciding with increased flows. Fish that have not arrived at the lower reaches during the high flows cease their migrations temporarily, and then recommence migration on the next flow event.
3. Spawning activity is concentrated in the lower freshwater reaches.
4. Following downstream migration, most individuals return upstream to the area they previously occupied.

4.1.2 Macroinvertebrates

Macroinvertebrates are often used as indicators of river health due to their sensitivity to changes in catchment use, pollution and habitat preference. In addition, macroinvertebrates break down organic matter and provide a food source for many animals higher up the food chain (eg.fish, birds and platypus).

Data collected by the EPA in 1998 and 2000 show that the macroinvertebrate community at She Oaks was in good condition with relevant biological metrics meeting or exceeding State Environment Protection Policy (SEPP) objectives. This indicates that in general, at this site, and prior to Millennium Drought and regional floods, that the macroinvertebrate community diversity was high and not limited by habitat availability or water quality. AUSRIVAS predicts the macroinvertebrates which should be present in specific stream habitats under reference conditions (EPA, 2000) whereas SIGNAL scores provide an indication of the level of pollution, based on the types of invertebrate families collected at that site (Chessman, 1999).

Macroinvertebrate assessments have also been completed as part of the Index of Stream Condition (ISC) assessments in 1999, 2004 and 2010 (Table 4.2). ISC combines different river health assessment protocols (SIGNAL, AUSRIVAS, EPT) into a single index referred to as Aquatic Life, and since 2010 has also included the number of Families. It is difficult to directly compare ISC scores across years because of slight changes in the way Aquatic Life scores have been calculated. In general, the 2010 scores indicate macroinvertebrate communities are in moderate to very good condition with the majority of taxa expected to be recorded in surveys. In particular, sites in Reaches 3a and 3b are in good to very good condition. Further downstream, sites in Reach 4 are also generally in good condition, although moderate SIGNAL Scores (score of 2 out of 4) do indicate some water quality impacts. Sites in Reach 2 are generally in poor condition with fewer families present than expected, while sites in Reach 1 are in poor to very good condition (depending on site specific locations).

Community-based Waterwatch surveys in 2007 at 3 sites downstream of Lal Lal Reservoir in reach 3a reported the macroinvertebrate community to be in very good condition (Waterwatch, 2007), with good numbers of sensitive taxa present (e.g. mayfly, dragonfly, stonefly and caddis fly larvae). Waterwatch surveys in 2013 reported similar conditions (Corangamite Waterwatch Program unpublished). The taxa present in reaches 3a and

3b downstream of Lal Lal Reservoir are those that require permanent, well oxygenated flowing conditions through riffle habitats.

The common decapod species of yabby, spiny cray, burrowing cray and freshwater shrimp have also been recorded from the Moorabool River system (NRE 1999). Raadik and Koster (2000) caught the Southern Victorian spiny cray at four sites between Batesford and She Oaks Weir in 1998.

Table 4.2. Macroinvertebrate AUSRIVAS, SIGNAL and Number of Families biometric scores and consequent ISC Aquatic life score (http://ics.water.vic.gov.au/ics/).

		1999			**2004**			**2010**			
FLOWS Reach	ISC Reach	AUSRIVAS#	SIGNAL#	ISC Aquatic Life score	AUSRIVAS#	SIGNAL#	ISC Aquatic Life score	AUSRIVAS / key families#	SIGNAL	No. families#	ISC Aquatic Life score
Moorabool River East Branch (Reach 1)	10	4	0	**5**	-	-	**-**	2	3	1	**4**
	11	4	3	**9**	-	-	**-**	3	3	3	**6**
	12	-	-		4	3	**9**	3	2	4	**8**
Moorabool River West Branch (Reach 2)	6	2	4	**8**	-	-	**-**	1	3	1	**4**
Moorabool River West Branch (Reach 3a)	5	2	4	**8**	4	3	**9**	2	2	3	**6**
Moorabool River (Reach 3b)	3	-	-	**-**	3	3	**8**	3	2	4	**8**
	4	-	-	**8***	-	-	**8***	4	3	4	**8**
Moorabool River (Reach 4)	1	2	4	**8**	-	-	**-**	3	2	3	**7**
	2	-	-	**-**	-	-	**8***	2	2	3	**6**

AUSRIVAS, SIGNAL and Number of Families biometric scores are rated out of 4.
^ ISC Aquatic Life scores are rated out of 10.
* Score extrapolated from similar nearby reach

4.1.3 Mammals

The Australian Platypus Conservancy (APC) conducted platypus live-trapping surveys in all reaches of the Moorabool River from 2003 to 2006 (Williams 2005; Williams and Serena 2004; 2006), with additional platypus live-trapping records subsequently generated as a by-product of fish surveys (McGuckin and Ryan 2009). In brief, the findings from these studies were as follows:

Surveys in Reach 1 and 2 in January 2004 and 2008 failed to record platypus and habitat quality at all sites was deemed to be poor. Three landholders interviewed by APC staff in 2006 reported seeing platypus on a reasonably regular basis on their respective properties from the 1950s-2006. All sightings were associated with reliably perennial aquatic habitats associated with deep pools and/or maintained by springs flowing in dry periods. Surveys in Reach 3a resulting in the capture of one adult or sub-adult female in 2006. Surveys in Reach 3b captured four animals and more individuals were captured in 2008. Importantly, a very high proportion of adults or sub-adults captured in this reach were females (79%). Indicating that this reach had (and presumably still has) outstanding value as a platypus breeding area. Reach 4 surveys in 2003/2006 captured four animals. However, only 28% of captured adults and sub-adults were females Live-trapping surveys indicate that platypus were widely distributed along the Moorabool River downstream of Lal Lal Reservoir in the mid-2000s, with up to four individuals captured overnight at a single site (Williams, 2005; Williams & Serena, 2004, 2006). Population size undoubtedly shrunk when flow ceased along much of the Moorabool in the final years of the millennium drought, with the species still likely to be in a post-drought recovery phase., implying platypus habitat quality was substantially lower on average in Reach 4 than in Reach 3b.

Figure 4.3 Platypus captured in reach 4 of the Moorabool River, Fyansford (Photo: DEDJTR, Oct 2015)

Based on the information presented above, the Moorabool River supported a widespread and substantial platypus population in the mid-2000s. Reach 3b apparently providing the most favourable habitat for breeding, with adult or sub-adult females also confirmed to occur in Reaches 3a and 4. Although platypus continued to be found in Reaches 1 and 2 in the mid-2000s, their status appears to have been relatively sparse and fragmented, ultimately limited by patchy availability of reliable surface water in summer as well as badly degraded habitat in some areas (notably Reach 2). The Moorabool River platypus population is also appropriately viewed as contributing to the genetic integrity and demographic sustainability of a larger platypus metapopulation encompassing the Moorabool, Barwon and Leigh River catchments (Jacobs, 2015). To maintain metapopulation viability, it is imperative that opportunities and pathways for safe movement by dispersing juveniles and breeding age males is successfully maintained among these three river systems.

Figure 4.4 Water Rat captured in reach 4 of the Moorabool River, Fyansford (Photo: DEDJTR, Oct 2015)

Water-rat (Hydromyschrysogaster) population density generally appeared to be greatest at the downstream end of the river. In Reaches 3b and 4 (where each site was surveyed on 2-3 occasions), water-rats entered nets at all of the nine survey sites in Reach 4 (100%) compared with four of seven sites contained in Reach 3b (57%). In Reaches 1, 2 and 3a where six sites were collectively surveyed on one occasion each, water-rat activity was recorded at 1 of 4 survey sites in Reach 2 as paw prints in mud (25%) The Moorabool River appears to have supported a widespread and at least reasonably sizable water-rat population in the mid-2000s, especially in

Reach 4. Although water-rats are opportunistic predators and scavengers, their diet is typically dominated by fish and large aquatic macro-invertebrates (Watts and Aslin 1981). Water-rats also become reproductively senescent by the age of 3-4 years (Olsen 1982), so local populations may virtually disappear if reproduction fails for three or more consecutive years in response to drought. Although no studies have been conducted to quantify Water-rat population recovery following drought, vacant habitats may be recolonised quite rapidly by these animals when conditions improve. This reflects their relatively high reproductive rate in favourable environments along with increased mobility.

4.1.4 Waterbirds

The Moorabool River system provides important habitat for waterbirds birds in central Victoria. Permanent pools are of particular value as these provide refuge and food resources over summer and during periods of drought.

A total of 11 Victorian threatened waterbird species have been recorded within the Moorabool River catchment downstream of Moorabool Reservoir and Bostock Reservoir (SKM, 2004b) (Table 4.3). This is not a representative list of all water dependant birds in the Moorabool. The list includes the endangered Little Egret (*Egretta garzetta*), Intermediate Egret (*Ardea intermedia*) and the Great Egret (*Ardea alba*). Five species are listed under the FFG Act 1988 and one species (Brolga) is listed under the EPBC Act. The Great Egret is also declared internationally significant by the Japan and Australia Migratory Bird (JAMBA) and China and Australian Migratory Bird (CAMBA) Agreements.

Table 4.3. Threatened waterbird species recorded in the Moorabool River catchment (SKM, 2004b).

Scientific name	Common name	Conservation Status	JAMBA / CAMBA4	Last recorded
Porzanapusilla	Baillon's Crake	Threatened1and vulnerable3		1985
Grus rubicunda	Brolga	Threatened1,2 and vulnerable3		1992
Platalearegia	Royal Spoonbill	Vulnerable		1995
Egrettagarzetta	Little Egret	Threatened1and Endangered3		2001
Ardea intermedia	Intermediate Egret	Threatened1and Endangered3		2001
Ardea alba	Great Egret	Threatened1and Endangered3	J, C	2001
Nycticoraxcaledonicus	Nankeen Night Heron	Vulnerable3		2001
Anasrhynchotis	Australasian Shoveler	Vulnerable3		2001
Aythyaaustralis	Hardhead	Vulnerable3		2001
Oxyuraaustralis	Blue-billed duck	Threatened1and Endangered3		2000
Biziuralobata	Musk Duck	Vulnerable3		2000

[1.] Listed under the*Flora and Fauna Act* 1988;
[2.]Listed under the *Environment Protection and Biodiversity Conservation Act* 1999
[3.] Listed on the advisory list of threatened vertebrate fauna in Victoria (2013 list).
[4.]Treaties: C-CAMBA; J-JAMBA

Figure 4.5: Remnant riparian woodland along reach 4 of the Moorabool River (Photo: Saul Vermeeren 2015)

4.1.5 Vegetation (flora species & Ecological Vegetation Communities)

In the bed of the channel are submerged and emergent macrophytes making up the “aquatic zone” species. On to the edge of the channel emergent amphibious species make up the “marginal zone”. Higher up on the stream banks the plants are accustomed to less and less inundation. Macrophytes give way to the grasses, bushes and trees of the “damp zone”. Plants in the “damp zone” can access water in a number of ways; from capillary action of moisture wicking from the stream channel into the adjacent soil, directly from groundwater discharge, by having roots which reach down to the stream channel and/or from brief inundation during freshes and floods.

The condition of riparian vegetation in the Moorabool Catchment ranges from extensively cleared in the upper reaches (reach 1 & 2) to large tracts of remnant native vegetation in the mid reach (reach 3a&3b) and scattered remnant vegetation in the lower reach (reach 4). Riparian vegetation has many important roles such as acting as a filter for nutrients before they reach the waterway, as a source of organic inputs into the stream (leaves, trees and logs), providing habitat for native fauna and contributing to bank stability (SKM 2004).

In reaches 1 and 2 the (between Moorabool and Lal Lal Reservoirs) riparian vegetation is very degraded due to extensive clearing and unrestricted cattle access. Remaining vegetation consists of River Red Gum *Eucalyptus camaldulensis* scattered amongst willows (*Salix* spp.) and pasture grasses. Willows are a significant problem below the reservoirs and form obstructions that cause bank erosion and impede channel conveyance. The mid reaches of the Moorabool River riparian environments are, in general, less disturbed than upstream of Lal Lal Reservoir (Zampatti and Grgat, 2000). In some areas between Morrisons and Meredith excellent stands of native remnant riparian vegetation consisting of River Red Gum, Silver Wattle *Acacia dealbata* and Woolly Tea-tree *Leptospermum lanigerum* remain. The East Moorabool Gorge contains significant areas of remnant grasslands.

Table 4.4. Ecological Vegetation Communities found along the Moorabool River

Ecological Vegetation Community	**Status** (Victorian listing)
Creekline Herb-rich Woodland	Endangered
Riparian Woodland	Endangered

Ecological Vegetation Community	Status (Victorian listing)
Stream Bank Shrubland	Endangered
Escarpment Shrubland	Endangered
Valley Grassy Forest	Vulnerable
Plains Grassy Woodland	Endangered
Grassy Woodland	Endangered

Reach 3a –Vegetation at FLOWS assessment site

Reach 3a supports an open woodland of healthy Manna Gums with a scattered small tree and tall shrub layer of Blackwood, Silver Wattle, Hemp Bush, Woolly Tea-tree, Sweet Bursaria, Broad-leaf Tree Violet and Hazel Pomaderris (Jacobs, 2015). EVC mapping indicates this FLOWS assessment site supports Stream Bank Shrubland, however a number of the species present are also consistent with Riparian Forest (Hazel Pomaderris, Hemp Bush and Manna Gum). This vegetation type supports a high cover and diverse range of indigenous species. It has been invaded by a range of environmental weeds, none of which are particularly abundant. No species characteristic of environments with relatively high salinity characteristics were observed in this reach. This may be due to the flushing effect of consistent fresh water releases from Lal Lal Reservoir.

Reach 3b –Vegetation at FLOWS Assessment site

Reach 3b supports an open woodland of healthy, large old River Red Gums, with a few scattered Manna Gums. The occurrence of River Red Gum and Manna Gum in the same area indicates this reach is in the transition zone between the foothills and lowland plains. There is a scattered small tree and tall shrub layer of Blackwood, Silver Wattle, Hemp Bush, Woolly Tea-tree, Sweet Bursaria, Broad-leaf Tree Violet and Prickly Currant-bush. EVC mapping indicates this FLOWS assessment site supports Stream Bank Shrubland. This reach supports five riparian plant species which are characteristic of environments with relatively high salinity, indicating out-cropping ground water.

Reach 4 –Vegetation at FLOWS assessment site

Reach 4 supports an open woodland of healthy River Red Gums, some of which are very old and large. These trees have many hollow branches, which are an important resource for a diversity of birds and mammals. There is a scattered shrub layer of Tree violet and Tangled Lignum, with Blackwood occurring further downstream. This reach supports five riparian plant species which are characteristic of environments with relatively high salinity, indicating out-cropping ground water. Upstream of the site at Bakers Bridge Rd is protected from grazing and supports a dense growth of instream aquatic and littoral amphibious species. Downstream of the bridge vegetation is unprotected from grazing and stock are causing considerable damage to soils and vegetation, particularly on the banks and in the littoral zone.

Aquatic vegetation of the Moorabool

The aquatic macrophyte community in the Moorabool River was characterised by Zampatti and Grgat (2000) as containing species common to lentic (non-flowing) water bodies (eg. Elodea *Elodea canadensis*, Duck Weed genera unknown) especially in the lower reaches downstream of She Oaks. Elodea was recorded in 2015 which shows that this serious weed has persisted despite drouhgts and flood. Floating Azolla (Azolla sp.) was located in pools, woody debris along the bank edges, leaf litter and willow root mats were also common at field assessment sites (Zampatti and Grgat, 2000). Zampatti and Grgat (2000) noted that whist these species colonise rivers during the low flow period, during higher flows they were not displaced. Whilst aquatic macrophytes are important habitat for fish and macroinvertebrates, high densities of aquatic macrophytes may also be detrimental to aquatic fauna by causing low levels of dissolved oxygen, particularly overnight and in the early morning (Zampatti and Grgat, 2000).

Significant flora

Table 4.5. Threatened vegetation communities and flora species recorded within the riparian zone of the Moorabool River (includes species that are not flow-dependant)

Species/community	**Status (state & federal listings)**
Grassy Eucalypt Woodland of the Victorian Volcanic Plain, Natural Temperate Grassland of the Victorian Volcanic Plain, White Box-Yellow Box-Blakely's Red Gum Grassy Woodland and Derived Native Grassland.	Critically Endangered –EPBC Act
Threatened flora species	
Dwarf Spider-orchid *Caladenia pumila* Spiny Rice-flower *Pimeleaspinescens subsp. spinescens*	Critically Endangered –EPBC Act
Matted Flax-lily *Dianella amoena* Adamson's Blowngrass *Lachnagrostis adamsonii* Hoary Sunray *Leucochry sumalbicans var. tricolor* Maroon Leek-orchid *Prasophyllum frenchii* Button Wrinklewort *Rutidosis leptorrhynchoides* Metallic Sun-orchid *Thelymitrae pipactoides*	Endangered –EPBC Act
Clover Glycine *Glycine latrobeana* Leafy Greenhood *Ptero styliscucullata* Large-fruit Fireweed *Senecio macrocarpus* Swamp Fireweed *Senecio psilocarpus* Spiral Sun-orchid *Thelymitra matthewsii* Swamp Everlasting *Xerochry sumpalustre*	Vulnerable –EPBC Act
Swamp billy-buttons *Craspedia paludicola* Pale swamp everlasting *Helichrysum aff. reutidolepos* Swamp fireweed *Senecio psilocarpus* Swamp everlasting *Xerochry sumpalustre*	Vulnerable in Victoria –Victorian Rare & Threatened Database
Yarra gum *Eucalyptus yarraensis* Swamp Water-starwort *Callitriche palustris*	Unknown in Victoria –Victorian Rare & Threatened Database
Naked Sun-orchid*Thelymitracircumsepta*	Endangered in Victoria–Victorian Rare & Threatened Database

**Species recorded is based on the state wildlife database and the EPBC Act Protected Matters Search 2015.*

4.2 Ecosystem functions

Ecosystem function means the biological, geochemical and physical processes that take occur within an ecosystem. The Moorabool River supports and maintains critical habitats and populations for water dependent biota.

Environmental watering sustains:

- transportation and dilution of nutrients, organic matter and sediment
- provides for longitudinal habitat connectivity for flow dependent biota
- provides connectivity between various hydrogeological areas from the foothills to the Moorabool Gorge through the floodplain and the Barwon River.

4.3 Social values

4.3.1 Cultural heritage

Aboriginal peoples have lived in the area now known as the Corangamite region for thousands of generations. The Wadawurrung language was spoken throughout most of the area; other Traditional Owner language groups included the Kirrae Whurrong, Gadubanud, Gulidjan and Djargurd Wurrung (Clark, I 1990). What we often refer to as the natural environment of the region is in reality a cultural landscape. At the time of European settlement, the landscape had been lived in, used, managed and ultimately shaped by Aboriginal peoples over tens of thousands of years, just as much of today's landscape has been heavily shaped by the actions of those who have lived here since settlement. There are a large number of previously recorded aboriginal archaeological sites located along the Moorabool River and its tributaries. The majority of these comprise artefact scatters, scar trees, earth features, and potentially burial sites. Due to the culturally sensitive nature of these sites, their specific locations along the river cannot be identified. Some cultural values along the Moorabool are flow-dependant and could be supported through environmental watering.

4.3.2 Recreation

The Moorabool River supports other social values including camping, recreational fishing, bushwalking and boat sports such as canoeing. Recreational fishing brings visitors to the area, and with its close location for Melbourne residents, is a popular weekend destination.

4.4 Economic values

The Moorabool River supports a range of industries and businesses. Many farming enterprises are highly dependent on its water. The east and west branches are heavily regulated, including the Korweinguboora and Bostock Reservoirs on the east branch and the Moorabool and Lal Lal reservoirs on the west branch. The catchment contains more than 4000 dams, with an estimated total storage capacity of 14,401 ML. Modelling of farm dams indicates that the collection of water in farm dams results in a reduction in stream flow of 12,300 ML per year. The damned nature of the catchment, particularly in the upper reaches highlight the historic economic dependence on the rivers water. General economic values include:

- Water carrier for the irrigation districts, industrial and urban users
- Water source for urban and rural areas
- Tourism and recreation industries.

4.5 Conceptualisation of the site

The conceptual model illustrated in Figures 4.7 and 4.8 show how different flow components and ecological processes interact in reach 3b of the Moorabool River. The conceptual model is based on a cross-section downstream from She Oaks Weir at Sharps road. It illustrates how flows inundate different parts of the channel environment.

Figure 4.6: A photo of the cross-sectional profile site on the Moorabool River downstream of She Oaks Weir (Photo: Jacobs, 2015)

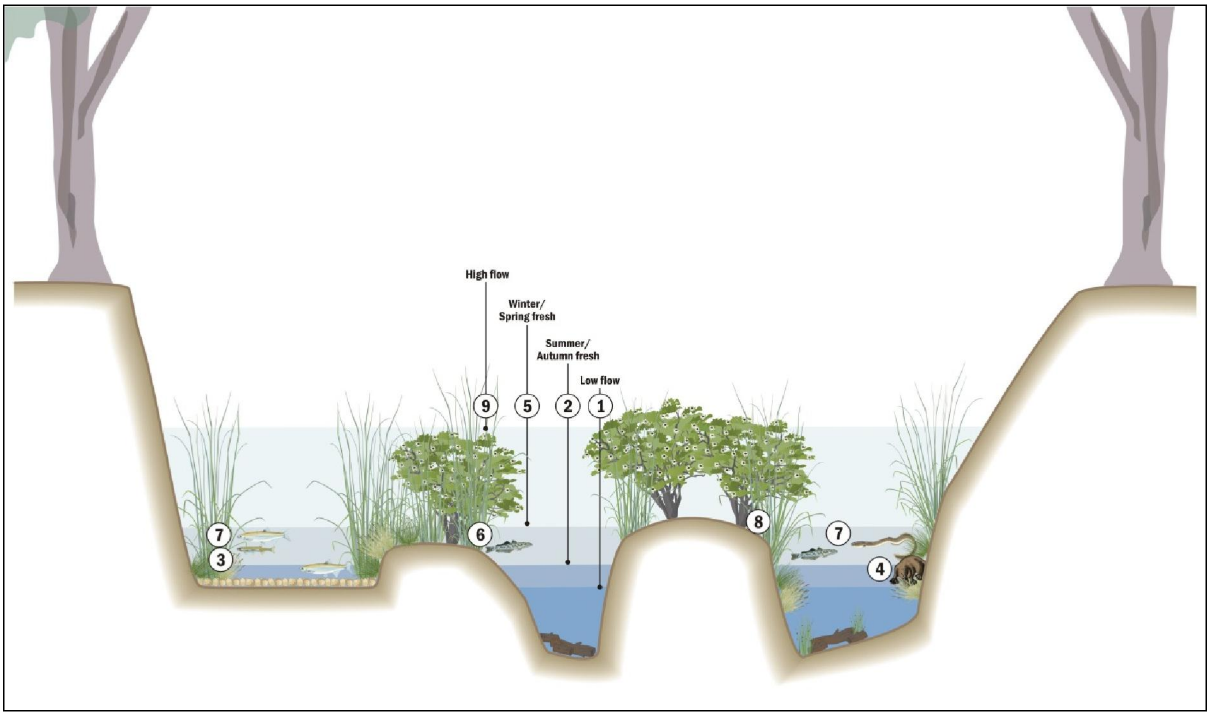


Figure 4.7: Conceptual model for the Moorabool River downstream of She Oaks Weir using a cross-sectional profile (Jacobs, 2015).

In explanation:

- Low flows throughout the year (1) are important in maintaining pool and riffle habitats for fish, macroinvertebrates, platypus and submerged aquatic vegetation. Some sections of the channel bed, in particular at the channel margins remain dry during low flows (3).

- Summer/Autumn freshes (2) flush silt and scour biofilms and algae from the streambed, water fringing semi-emergent vegetation (3) and allow greater access to habitat areas for fish and platypus (4). These freshes will also inundate a greater proportion of the channel bed, in particular backwater pockets at the margins of the channel (3). Freshes are also required to trigger downstream spawning migration of Short-finned Eel in January/February and Grayling in April/May.

- Winter/Spring freshes (5) provide increased opportunities for movement of fish and platypus throughout the reach and maintain access to habitat. Freshes are also required to trigger downstream spawning migration of adult Tupong in May to August (6) and upstream migration of juvenile Galaxias, Tupong, Short-finned Eel and Grayling from September to November (7). These freshes will also flush silt and scour biofilms and algae from the streambed, transport organic matter and promote the growth and recruitment of native riparian vegetation (8).

- High flows (9) scour pools and maintain channel form and dimensions. They may also engage billabongs in the lower reaches.

The conceptual model in Figure 4.8 illustrates how different flow components influence flow connectivity and provide opportunities for migration of fish past barriers.

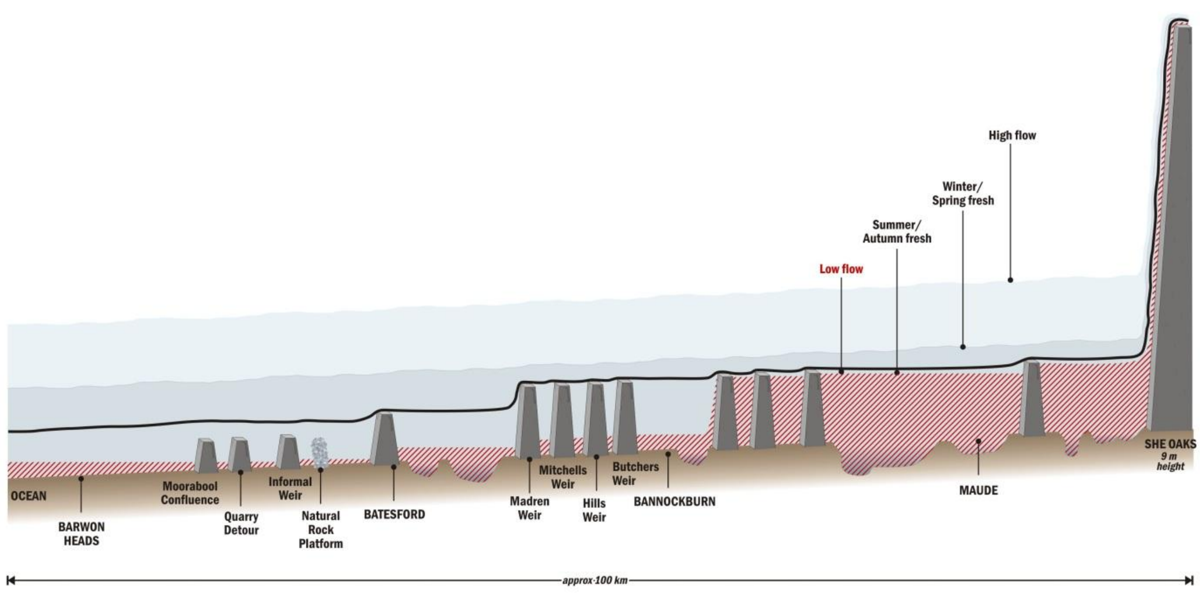


Figure 4.8: Long-section conceptual model of reach 3a and 3b of the Moorabool River, downstream of She Oaks Weir to Southern Ocean (Jacobs, 2015).

In explanation:

- At very low flows, there is limited connectivity of flow along the river and fish movement is restricted to sections between natural and artificial barriers.

- Summer/Autumn freshes provide opportunities for movement in the lower Moorabool River, in particular the section of river downstream of Batesford Weir as smaller natural and artificial weirs are downed out. These freshes allow greater access to habitat areas for fish and platypus and trigger downstream spawning migration of Short-fined Eel and Grayling.

- Winter/Spring freshes and High flows allow access to habitat areas for fish and platypus. Winter/Spring freshes and High flows allow upstream and downstream migration of fish, as all weirs and rock outcrops, with the exception of She Oaks Weir are drowned.

4.6 Significance

The Moorabool River system supports flora and fauna of national, state and local conservation significance. The vegetation communities along the river are some of the most endangered communities at both a state and federal level (refer to section 4.1 Environmental Values). These vegetation communities contribute to the biodiversity of Victoria and provide habitat for many threatened animal species that depend on the structure and composition of these vegetation communities. Remnant vegetation is threatened by farming practices in or adjacent to riparian corridors, urban development, habitat fragmentation and altered flow regimes. Furthermore, the river has highly variable natural flows and the diverse range of biota reflects this flow variability.

Figure 4.9: A deep habitat pool within the Moorabool gorge (Photo: Saul Vermeeren 2015)

4.6.1 Moorabool Gorge

The Moorabool Gorge stretches along approximately 7kms of the Moorabool River, near Meredith. The gorge is not only important environmentally, but it is of particular significance to the community for its swimming, fishing and its aesthetic values. Its 100-200m steep escarpments remain largely non-arable, protecting bands of remnant vegetation and providing important corridors of habitat for wildlife.

The unique geomorphological characteristics of the Moorabool River create various channel bank and bed formations and as a result the river contains a diversity of habitat types including a number of deep habitat pools. During periods of drought, deeper habitat pools provide refuge for many fauna and flora species, and once flows are reinstated during wetter years these species are able to expand and recolonise inundated areas through channel connectivity. Habitat refuge pools are a critically important component of the river's ecosystem and contribute to the resilience of the system. These areas are key areas to protect through the environmental watering program.

4.6.2 Biodiversity habitat corridor

The Moorabool River provides a significant biodiversity habitat corridor between the Central Highlands, Victorian Volcanic Plains and through to the Southern Ocean at Barwon Heads. This 200km habitat corridor links the Brisbane Ranges National Park to the Moorabool's local river reserves in the Victorian Volcanic Plain before feeding into the Barwon River reserve and Ramsar-listed Lower Barwon Wetlands. This habitat corridor sustains life and critical ecological process for many species of native flora and fauna. It also provides a level of resilience for species by allowing them to disperse between habitats depending on their needs. Often overlooked, is the important role that biodiversity corridors play in supporting flora seedbanks and allowing the dispersal of seed and subsequent colonisation of native vegetation across landscapes.

The Moorabool provides contributing freshwater flows to the Barwon River system and the internationally significant Ramsar-listed Lower Barwon Wetlands (Lake Connewarre wetlands complex).

5 Ecological condition and threats

5.1 Current condition

The Third Index of Stream Condition (ISC) Report for 2010 describes the East Moorabool River (Reach 1) as being in poor to moderate condition and the West Moorabool River (Reaches 2 and 3a) as being in moderate condition. The section of river from the confluence of the East and West Branches to Sharps Rd, She Oaks (Reach 3b) is assessed as being in moderate condition, and the river downstream from She Oaks Weir (Reach 4) as being in very poor condition. Scores for the five sub-indices that together give the overall condition are shown in Table 5.1 below.

Table 5.1: 2013 ISC Assessment for the Moorabool River (DEPI 2013b).

FLOWS Reach	ISC Reach	Hydrology	Physical Form	Streamside Zone	Water quality	Aquatic Life	ISC Score	Condition
East Moorabool River (Reach 1)	10	4	6	7	4	4	**22**	**Poor**
	11	4	6	5	-	6	**24**	**Moderate**
	12	4	8	8	5	8	**29**	**Moderate**
West Moorabool River (Reach 2)	6	8	7	5	4	4	**24**	**Moderate**
West Moorabool River (Reach 3a)	5	8	7	8	6	6	**33**	**Moderate**
Moorabool River (Reach 3b)	3	8	6	8	5	8	**32**	**Moderate**
	4	8	7	6	6	8	**33**	**Moderate**
Moorabool River (Reach 4)	1	-	7	6	5	6	**19**	**Very poor**
	2	-	5	6	-	7	**18**	**Very poor**

5.2 Condition trajectory

A decline in the overall condition of the Moorabool River system is likely to occur over the next 10 years, unless there is an increase to the environmental entitlement or additional waterway management works (Jacobs, 2015).

Reasons for this projection are as follows. Passing flows from upstream storages do not meet minimum environmental water requirements required to maintain existing environmental values (Section 2.3). Opportunities for downstream and upstream movement of migratory fish species are limited as a result of the large reductions in river streamfllow and the presence of a number of artificial barriers. The majority of migratory fish species are restricted to the lower parts of the Moorabool River, downstream of Batesford Weir. Other ongoing impacts include stock access and degradation of the riparian zone, in turn degrading instream habitat, the downstream movement of sediment slugs due to land clearing and mining activities, diversion of the Moorabool River around the Batesford Quarry and associated losses of surface water to seepage.

The volume of water stored in the environmental flow entitlement is not sufficient to meet all of the environmental flow recommendations within a year and therefore inadequate to support ecological values. As discussed in Section 2.7 (see Figure 2.2 and Table 2.3.), there is no year since 2010 when all flow components required to achieve the ecological objectives for the Moorabool River have been delivered, not even in the wet year, 2012-2013, To date, environmental releases from Lal Lal Reservoir have been mainly during summer. This is primarily due to the differences in magnitude between summer and winter flow recommendations, delivery constraints at Lal Lal Reservoir (approximately 146 ML/day) and limits to the total volume of water available within the entitlement. Summer flow recommendations for Reaches 3a, 3b and 4 are to maintain base flows between 10 & 20 ML/day between December and May and provide three Summer Freshes of greater than 32 ML/Day for 10 days. The volume of water required to deliver the Summer flow recommendations (>4000 ML) exceeds the average yearly volume of water available for the entitlement (2500 ML/year). Summer releases by Barwon Water between Lal Lal Reservoir and She Oaks contribute to achievement of summer low flows.

Achieving all of the flow recommendations for the Moorabool River within the delivery constraints and environmental water availability is not possible. The recommended base flow for Reaches 3a, 3b and 4 is 83/86 ML/day between June and November. Two to three Winter Freshes greater than 146/162 ML/day for 5/10 days and a Winter High of greater than 3000 ML/day are also recommended. There is insufficient volume of water available in the environmental entitlement to meet the winter low flow recommendation (Jacobs 2015), however in wet years this can be met by high flows associated with high rainfalls and reservoir spills. The winter freshes are achievable in wet or average rainfall years, when these flows can be built on top of smaller event generated by rainfall over the catchment.

The current Moorabool River Environmental Entitlement only secures approximately 10% of the rivers environmental flow requirements. The 2015 FLOWS study has identified that an additional 18,000 ML is required to meet the environmental flow needs of the river (Jacobs 2015). The report also highlights that this currently may not be a realistic target for a river system that is also relied upon for social and economic needs of the region. Bearing this in mind, the study has identified that securing the ability to deliver 5,140 ML per year under dry conditions would be a minimum water recovery target that is achievable within the timeframe of this document, and is well justified from an environmental perspective but also demonstrates a balance outcome for other water users. Further information can be found in Section 6.3 Water Recovery Targets.

5.3 Water related threats

Flow diversion from major headworks to supply urban water, land use, licenced and unlicensed extraction have impacted both quantity and quality of flows with the Moorabool River receiving less than 50% of its natural stream flow in an average year and less than 25% in a drought year. Sedimentation and sand slugs brought about from flow changes and erosion from catchment clearing have also impacted on the habitat of fish species, as well as other social amenities, e.g. filling in swimming holes. Additionally, the Moorabool River is a major tributary to the Barwon River. As such, the flow-stressed nature of the Moorabool River impacts on the health of the lower Barwon River, including the Ramsar listed Lower Barwon wetlands (Lake Connewarre wetland complex).

The population of Geelong is expanding with residential developments occurring along the lower Moorabool River corridor in the Batesford and Fyansford growth areas. Urban growth has placed pressure on existing infrastructure and land use, with the potential for associated impacts to adversely affect the values of the area. Threats linked to urban development and increased recreational use include stormwater run-off and degraded water quality, soil disturbance, bank erosion and degradation of native vegetation.

Table 5.2 lists threats that relate directly to water dependant environmental values (Fish, Macroinvertebrates, Mammals, Birds, and Vegetation). Further detail on water dependant values is provided in chapter 4. Please note *Chapter Managing Risks to Achieving Objectives* provides the broader catchment impacts of these threats on achieving objectives.

Table 5.2: Threats to water dependent environmental values

Water dependent value	Threat	Consequence
Fish, Macroinvertebrates, Mammals, Birds, Vegetation	Reduced volume of water regime	Inability to achieve critical flow components to support ecological health and function of the Moorabool River
Vegetation	Native vegetation clearing (Altered physical form)	Increased bank instability from lack of bank vegetation and bank slumping, resulting in bank erosion and failure.
Fish, Macroinvertebrates	Poor water quality	Degraded water quality from increased light, temperature and nutrient levels, resulting in excessive instream macrophyte growth.
Fish, Macroinvertebrates	Degraded habitats	Reduced instream woody debris (snags), resulting in reduced habitat
Fish, Vegetation, Mammals	Invasive flora and fauna	Invasion of exotic vegetation and increase in non-native fish species, reducing native fish habitat and resources, and increasing predation of native fish.
Fish	Reduced connectivity	Creation of barriers to fish movement and reduced floodplain connectivity from levee building, resulting in reduced species migration and access to spawning habitat.

5.4 Climate change

The Corangamite CMA is currently developing a *NRM Plan for Climate Change*. This plan highlights the varying levels of climate stress placed on waterways in the Corangamite catchment and provides information on how to ameliorate or reduce the level of environmental impact caused by this threat. Climate change is a medium to long-term impact and generally outside the timescale and management focus of this EWMP, however, the EWMP can still provide some assistance in demonstrating measures to improve resilience and adaptation through monitoring and management activities.

Short-term management measures to respond to the threat of climate change are included in the annual environmental flow planning process which adjusts environmental flow release plans according to climate conditions and water availability. Medium-term impacts of climate change have been incorporated into *Table 7.2. Moorabool River qualitative risk assessment –managing risks to achieving objectives.* Medium-term management measures, such as native revegetation, connecting riparian corridors and river shading are included to improve resilience and adaptation to climate change.

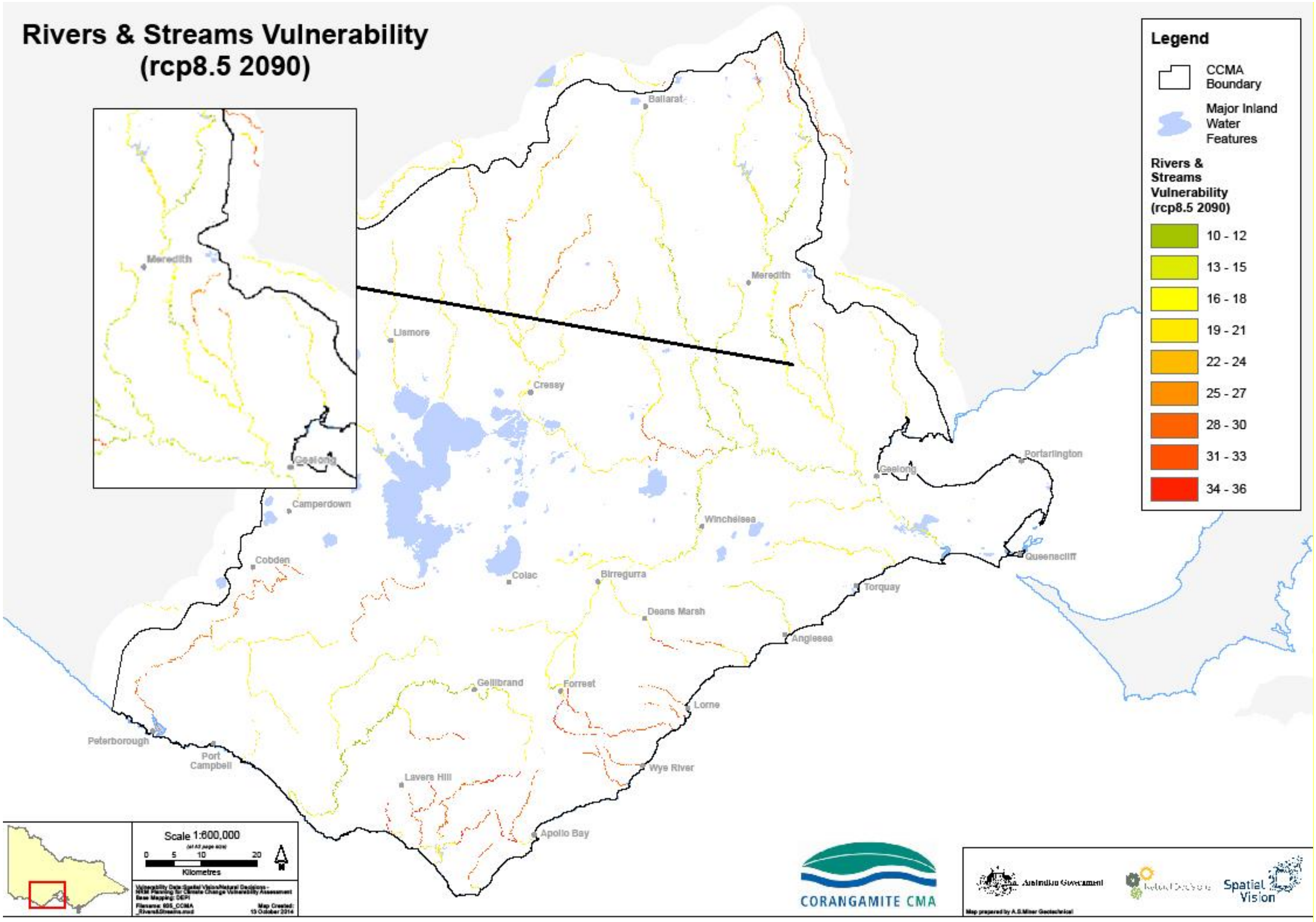


Figure 7.1: Rivers and streams vulnerability 2090 forecast, taken from NRM Plan for Climate Change (CCMA, 2015)

Figure 7.1 above identifies that the Moorabool River is at moderate vulnerability to a drying climate between now and 2090. A drying climate will cause a direct reduction in precipitation, catchment runoff and river flows. It is important to note, that this map presents the vulnerability of the river between 'its current state' and the year 2090. The river is already currently one of the most flow-stressed rivers in Victoria.

6 Management objectives

6.1 Environmental water management goal

To improve the Moorabool Rivers flow-dependent ecological values and services through the provision of environmental water. The delivery of environmental water will also provide for social and cultural values for future generations.

(The intent of this goal, developed by the Moorabool Stakeholder Advisory Committee, is to ensure the effective use of the current entitlement and highlight the need for additional water to maintain and improve environmental values)

6.2 Ecological objectives

The Moorabool River FLOWS Study Update (Jacobs, 2015) provided the avenue for revising the ecological objectives in collaboration with Jacobs Consulting, Corangamite CMA, Moorabool Stakeholder Advisory Committee and the FLOWS Scientific Advisory Committee. These ecological objectives were for recognised values to do with macroinvertebrates, vegetation, platypus, geomorphology and water quality.

Two fundamental mechanisms are required in order to meet the goal and ecological objectives of this EWMP, they include:

- **Water recovery**
- **Ecological response monitoring**

The ability to meet the EWMP goal of improving the Moorabool Rivers flow-dependant ecological values relies on improved environmental flow volumes. Without additional environmental water, the ecological values will continue to decline (Jacobs, 2015). Minimum and aspirational water recovery targets have been scientifically developed through the Moorabool River Flows Study Update (Jacobs, 2015) and are detailed in *Section 6.3 Water Recovery Targets & Flow Prioritisation.*

Monitoring is a fundamental requirement to be able to measure if ecological objectives have been met, therefore ecological response monitoring programs need to be implemented to assess the success or short-comings of the environmental watering program. Monitoring programs are described in *Chapter 9 Demonstrating Outcomes*.

Table 6.1 presents the ecological objectives, their function and the expected response for each reach within the Moorabool River system.

Table 6.1. Ecological objectives for the Moorabool River system

Ecological objectives		Ecological function	Expected response	Reach
Fish				
F1	Rehabilitate migratory species (tupong, short-finned eel, common galaxias, spotted galaxias, short-headed lamprey, Australian grayling)	Provide opportunities for upstream migration of adult anadromous and juvenile catadromous and amphidromous fish	Increased distribution, abundance and diversity of migratory fish species	1, 3a, 3b, 4
		Trigger downstream spawning migration of adult catadromous and amphidromous fish		
		Provide minimum flow depths for movement and dispersal (40 cm in pools and 20 cm in riffles)		
F2	Maintain and expand non-migratory fish species (flat-headed gudgeon, Australian smelt, southern pygmy perch, river blackfish)	Provide minimum flow depths for movement and dispersal (40cm in pools and 20 cm in riffles)	Increased distribution, abundance and diversity of non-migratory fish species	1, 2, 3a, 3b, 4
Macroinvertebrates				
M1	Maintain the diversity and abundance of macroinvertebrates suited to both slow and fast flowing habitats	Maintain access to riffles and LWD	Maintain abundance and biomass of macroinvertebrates	1, 2, 3a, 3b, 4
		Flush fine sediments and scour biofilms growing on benthic surfaces and large wood habitat	Maintain a diverse mix of cleared areas and areas with benthic algae	
Vegetation				
V1	Maintain aquatic zone species	Provide sufficient depth of water to maintain instream vegetation	Maintain diversity of instream vegetation	1, 2, 3a, 3b, 4
		Limit terrestrial encroachment, scour periphyton and flush Elodea		
V2	Maintain marginal zone species	Provide flow variability to maintain species diversity of fringing vegetation	Maintain and promote growth of fringing vegetation	1, 2, 3a, 3b, 4
V3	Maintain damp zone species	Maintain adult specimens and provide cues for successful recruitment of juveniles.	Maintain riparian zones plus successful recruitment of juveniles into the population	1, 2, 3a, 3b, 4
V4	Maintain inset benches/floodplains	Maintain diversity of vegetation	Maintain riparian zones plus successful recruitment of juveniles into the population	1, 2
	Maintain inset floodplains			3a, 3b
	Maintain floodplain wetlands			4
Platypus				
P1	Maintain platypus population, particularly in refuge pools during dry years	Provide sufficient flow depth to maintain access to foraging habitat, food supply and maintain water quality	Capable of supporting populations of platypus in refuge	1, 2

Ecological objectives		Ecological function	Expected response	Reach
	Restore self-sustaining breeding population of platypus		pools	3a, 3b, 4
P2	Support dispersal of juvenile platypus to/from the Barwon River			3a, 3b, 4
P3	Support movement of adult males to/from the Barwon River			4
Geomorphology				
G1	Maintain channel form and processes	Engage benches. Maintain channel and scour pools.	Maintain channel complexity, pools and benches	1, 2, 3a, 3b, 4
G2	Maintain inset floodplains	Engage and maintain floodplain processes	Maintain floodplain features	1, 2, 3a, 3b
	Maintain floodplain	Engage billabongs and maintain floodplain processes		4
Water quality				
W1	Prevent low dissolved oxygen conditions and elevated EC conditions during low flow periods	Connecting flow sufficient to maintain water quality	Continuously flowing water and occasional freshes will prevent the development of adverse water quality conditions.	1, 2, 3a, 3b, 4
W2	Prevent blackwater events that lead to fish kills	Transport organic matter that has accumulated in the channel over winter and summer periods	Winter fresh needs to precede Summer fresh to minimise potential for blackwater events	1, 2, 3a, 3b, 4

6.3 Water recovery targets

This section provides details of the water recovery targets that are required to safeguard the rivers environmental values for conservation and for future generations. It includes minimum and aspirational water recovery targets that are based on the achievement of prioritised flow components that were developed as part of the Flows Study (Jacobs 2015).

The *Sustainable Water Strategy -Central Region* (DSE, 2006) identified the need for a 5000 ML water recovery target for the Moorabool Rivers environmental water reserve. This target was initially validated by the Moorabool River Water Resource Assessment (SKM 2003) and has since been scientifically tested through the completion of the Moorabool River Flows Study Update (Jacobs 2015) and an independent scientific panel. The current Moorabool River Environmental Entitlement 2010 (the entitlement) was established to protect the Moorabool Rivers water dependent ecological values. The entitlement can be used to deliver environmental flows to reaches 3a, 3b and 4. The 7086 ML volume entitlement is subject to delivery rules (a maximum of 7500 ML over three years) with an average of 2500 ML per year available to be used (subject to water availability). While the establishment of the entitlement in 2010 was a big step forward in protecting the life of the river, the volume held within the entitlement falls far short of what is required to achieve the minimum flow requirements that are required to protect ecological values. The Moorabool River is one of the most flow-stressed rivers in Victoria and the current entitlement provides approximately 10% of the water required to maintain its ecological values.

The water recovery targets have been developed using historical flow conditions. This includes flows delivered by the Corangamite CMA and Barwon Water Bulk Entitlements, and assumes existing flow inputs and conditions remain unchanged and are status quo.

Without additional environmental water, the ecological values of the Moorabool River will continue to decline (Jacobs, 2015). Table 6.2 provides a breakdown of the minimum and aspirational water recovery targets.

Setting of minimum and aspirational flow recommendations

Minimum and aspirational flow recommendations have been set for the Moorabool River reaches. A minimum flow recommendation refers to the minimum amount of water that is required to meet the highest priority ecological objectives (please note not all ecological objectives would be met). These recommendations relate directly to the water recovery targets. Aspirational flow recommendations are those of a higher magnitude which are recognised as providing a greater benefit to the system and a higher likelihood of achieving river health outcomes.

For reaches 1 and 2, given there is no environmental entitlement available, all of the flow recommendations are set as minimum flow recommendations. Aspirational flow recommendations have not been set for these reaches as there is not sufficient ecological justification to set higher aspirational flow recommendations.

For reaches 3a, 3b and 4, all of the Summer/Autumn flow recommendations are classified as minimum flow recommendations. The minimum flow recommendations in the Winter/Spring season allow for fish and platypus movement, maintain access to habitat and assist in scouring of biofilms and algae from the streambed and transport of organic matter. Minimum depths for movement of fish and platypus will be provided by low flows and triggers for fish movement are provided by the smaller fresh events.

It is recognised that there would be greater benefit if a higher aspirational low flow was provided, with increased wetting of the perimeter of the channel, allowing more access to a greater area and diversity of instream habitat. Similarly, relative to the higher aspirational low flow, higher magnitude freshes with longer duration may be more beneficial in scouring biofilms from the bed, transporting organic matter and triggering fish migration. Aspirational flow recommendations are only likely to be achieved in very wet years at present.

Table 6.2: Estimated annual ML volume of water required to meet minimum and aspirational water recovery targets (flow recommendations) in reaches 3a, 3b and 4 (Jacobs 2015).

FLOWS	Wet/Average		Dry	
Reach	Minimum	Aspirational	Minimum	Aspirational
3a	6,150	18,970	3,380	14,620
3b	9,000	25,700	5,140	19,630
4	9,000	36,050	5,140	19,630

Minimum water recovery target 1

The Minimum Water Recovery Target 1 would enable the delivery of 5,140 ML/year under dry conditions. Importantly, this would require an additional allocation of 2640 ML/year to the existing entitlement, and would require carefully considered changes to the bulk entitlement rules, including alterations to share of storage capacity and inflows. This is a realistic target that has been developed in consideration of the rivers other water resource users. It does not provide all of the environmental water needs for the Moorabool. Rather, it would provide the critical minimum environmental water volume to protect the highest priority ecological values.

- **enable the delivery of 5,140ML/year under dry conditions**

Minimum water recovery target 2

The Minimum Water Recovery Target 2 would enable the delivery of 9,000 ML/year under wet/average conditions. This would require carefully considered changes to the bulk entitlement rules, including alterations to share of storage capacity and inflows. This target provides the minimum environmental water volume to protect priority ecological values under wet/average conditions.

- **enable the delivery of 9,000ML/year under wet/average conditions**

Aspirational water recovery target 3

The Aspirational Water Recovery Target 3 would enable the delivery of 19,630 ML/year. This target is based on the delivery of all of the recommended flow components (low flows, freshes and high flows) in all seasons in a year, and protection of all of the systems identified ecological values. While it would protect the river’s values, the target is not equivalent to river flows prior to European settlement.

- **19,630 ML/year**

6.4 Moorabool River Flow Priorities

Environmental flow recommendations to support the Moorabool Rivers ecological values were updated through the Moorabool River FLOWS Study Update (Jacobs, 2015). The existing recommendations were reviewed and updated using current scientific information by the Flows Study Scientific Panel (Scientific Panel) in multiple workshops on 28 May 2015 conducted by Jacobs Consulting in collaboration with the Corangamite CMA. The Scientific Panel worked through the process of updating the flow recommendations on a reach by reach basis. For each reach the revised ecological objectives and previous flow recommendations were discussed. Photos and field notes taken during the field assessment were examined along with transects from the hydraulic models in order to identify key habitat features i.e. benches, pools, riffles, backwaters etc.

Every flow component was considered in each reach. A range of criteria were used to determine suitable flows (i.e. depth in riffles and pool, water quality). These criteria are reach specific and vary according to the species present and channel features. For each flow component the desired volume threshold, frequency of occurrence and duration was determined. Consideration was given to the acceptable level of variability in flow components and differences between wet, average and dry years.

All values identified have components of their life-cycle or process that are dependent on particular water regimes for success e.g. native fish require certain timing, duration and frequency of flooding to successfully breed and maintain their population. Requirements for the frequency, duration, and timing have been identified and described for all of the ecological objectives. To meet the 'long-term' requirements of the Moorabool River EWMP, flow recommendations have been set considering the following factors:

- Preferred timing of watering events
- Recommended duration for watering events
- Tolerable intervals between events (condition tolerances)
- Volume required to provide these events – per event/season.

Flow seasons

Flow recommendations are separated into two flow seasons within a year, being either the summer/autumn or winter/spring. For planning purposes, the summer/autumn flow recommendations apply to the whole period from the start of December to the end of May. Winter/spring flow recommendations apply from the start of June to the end of November.

Adapting flow recommendations for wet, average and dry years

This plan provides environmental flow recommendations based on different climate scenarios, including wet average and dry years. Adapting flow to climate scenarios allows a level of flexibility for planning water releases, for example, higher magnitude events in wet years compared to dry years due to higher catchment runoff, increased passing flow releases and potentially more water available within the environmental water entitlement. Conversely, in dry years there is less water available to implement all of the environmental flow recommendations. Planning for each seasonal scenario also considers prioritisation of flow components, to inform management decisions. The division of wet, average and dry years was based on the long-term rainfall record at Moorabool Reservoir, which has 102 years of record, as well as water availability (applicable to reaches 3a, 3b and 4) and the environmental objectives.

6.4.1 Prioritisation of flows

Flow prioritisation is an important part of flow delivery planning for the Moorabool River due to the limited amount of water available within the environmental entitlement. Prioritisation can help inform (not necessarily determine) water delivery options to achieve the greatest environmental benefit.

The flow priorities for Reaches 3a, 3b and 4 of the Moorabool River are based on the Moorabool River Flows Study Update, and are as follows:

6. **Provision of trigger-based freshes *(drought scenario only)**
7. **Provision of base flows**
8. **Provision of priority 1 freshes**
9. **Provision of priority 2 freshes**
10. **Provision of priority 3 freshes**

Figure 6.1 provides a diagrammatic representation of each flow component and the timing of priority freshes 1, 2 and 3. Please note, the recommended volumes of high flow events exceed the capacity of the Lal Lal reservoir outlet and can only be achieved via natural catchment inflows and/or spilling of Lal Lal reservoir.

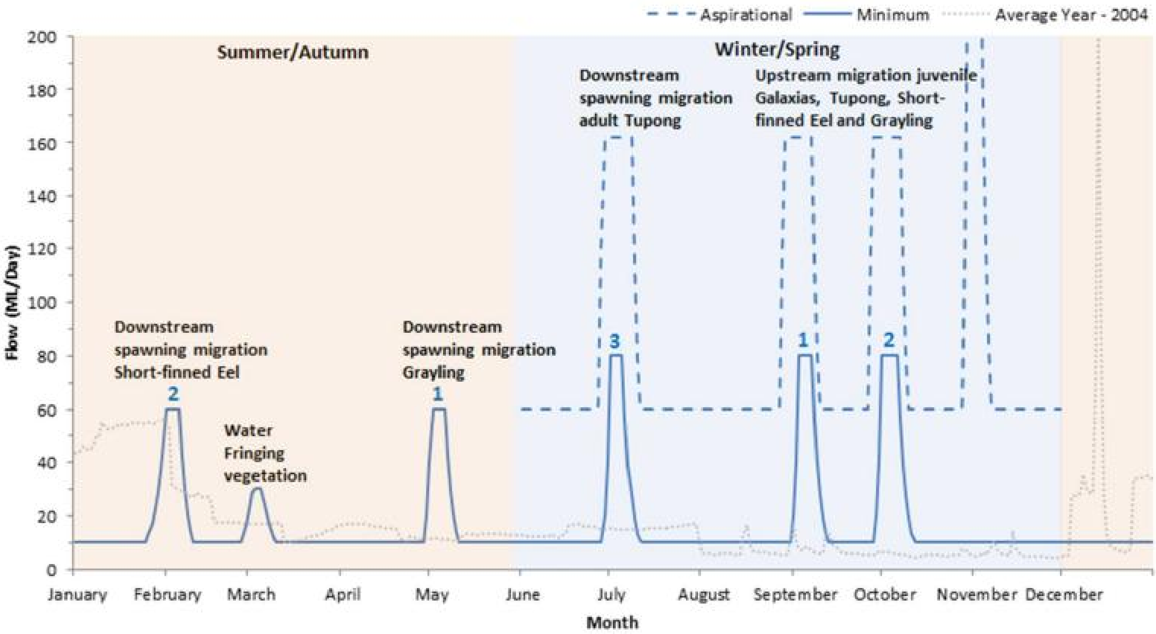


Figure 6.1: Example plot showing environmental flow priorities for Reach 3a, during an average year. Please note that only fresh events have been prioritised.

There will be periods where there is limited water available to provide continuous recommended low flows. Given these constraints, the first priority is to provide a summer/autumn base flow that maintains suitable water quality. This may be lower than the recommended low flow. Should water conditions deteriorate a priority will be placed on the delivery of trigger-based freshes to improve water quality conditions. In the Moorabool Catchment, freshes in summer/autumn and winter/spring are important for triggering the movement and spawning of migratory fish species. The following prioritisation will be applied to the delivery of freshes:

- In summer/autumn, a higher priority is placed on delivering the April/May fresh to trigger downstream spawning/migration of Australian grayling over the January/February fresh which triggers the downstream spawning/migration of short-finned eel.
- In winter/spring, first priority is to deliver one fresh in September/October to trigger upstream migration of galaxids and Australian grayling followed by a fresh in June/July to trigger downstream spawning/migration of tupong as a second priority. An additional fresh in September/October is third priority, providing another opportunity for galaxids and Australia grayling to move upstream.

6.4.2 Hydrological objectives and flow recommendations

Tables 6.3 to 6.7 provide a summary of the flow recommendations for all reaches of the Moorabool River as detailed in the Flows Study Update, and as they relate to the ecological objectives. Figures 6.2 to 6.9 provide a visual representation of the flow recommendations summarised in the tables (Jacobs, 2015).

Table 6.3. Environmental flow recommendations for Reach 1 – Moorabool River East Branch: Bostock Reservoir to West Moorabool River.

Season	Flow	Hydrological objectives (Ecological objectives)	Wet/ average/ dry	Magnitude	Frequency and timing	Duration	Rise / fall*
Summer / Autumn (Dec–May)	Low flow	Maintain pool and riffle habitats for fish, macroinvertebrates, platypus and submerged aquatic vegetation (F1, F2, M1, V1, P1, P2, P3). Maintain water quality (W1).	All years	1.2 ML/Day	December to May		
	Fresh	Water fringing marginal zone vegetation (V2, V3). Allow fish and platypus movement through the reach and maintain access to habitat (F1, F2). Prevent low dissolved oxygen conditions and elevated EC conditions during low flow periods (W1).	Dry	2 ML/Day	Every 8 weeks	2-3 days	2/0.7
Winter / Spring (Jun-Nov)	Low flow	Allow fish movement throughout the reach (F1, F2). Maintain clear flow path and control intrusions by terrestrial vegetation (V1).	All years	8 ML/Day	June to November		
	Fresh	Allow fish and platypus movement through the reach and maintain access to habitat (F1, F2). Trigger downstream spawning/migration of tupong. Upstream migration of galaxias and grayling (F1). Flush silt, and scour biofilms and algae from streambed (M1) and transport of organic matter (W2). Promote growth and recruitment of native riparian vegetation including woody shrubs and promote strong vegetation zonation on the banks (V2, V3).	Wet / Average	37 ML/Day	1 event in June/July (tupong) and 2 events in September/ October (galaxias and grayling)	5 Days	2/0.7
			Dry	37 ML/Day	1 event in June/July (tupong) and 1 event in September/ October (galaxias and grayling)	5 Days	2/0.7
	High flow	Scour pools and maintain channel form and dimensions (G1). Inundate benches and inset floodplains (G2, V4). Flushing of sediment to improve spawning sites (F2).	Wet / Average	500 ML/Day	1 event every 2 to 3 years, preferably in Winter to avoid risks to platypus (no control over timing)	2 Days	2/0.7
			Dry	Not expected			

*Recommended rates of rise/fall are provided as a factor of the previous days flow and have been determined based on assessment of daily flow data recorded at flow gauges downstream of all storages in the Moorabool River (SKM 2004b).

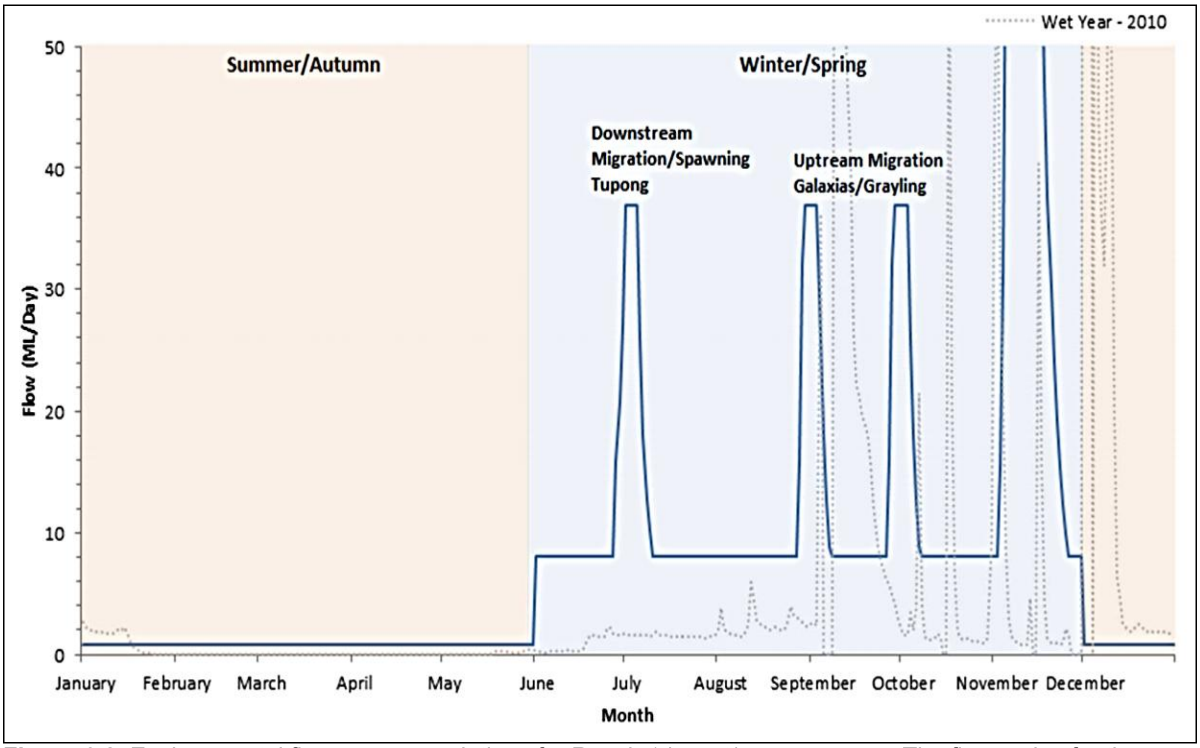


Figure 6.2. Environmental flow recommendations for Reach 1 in wet/average years. The flow series for the year 2010 is shown as an example of a year experiencing wet flow conditions.

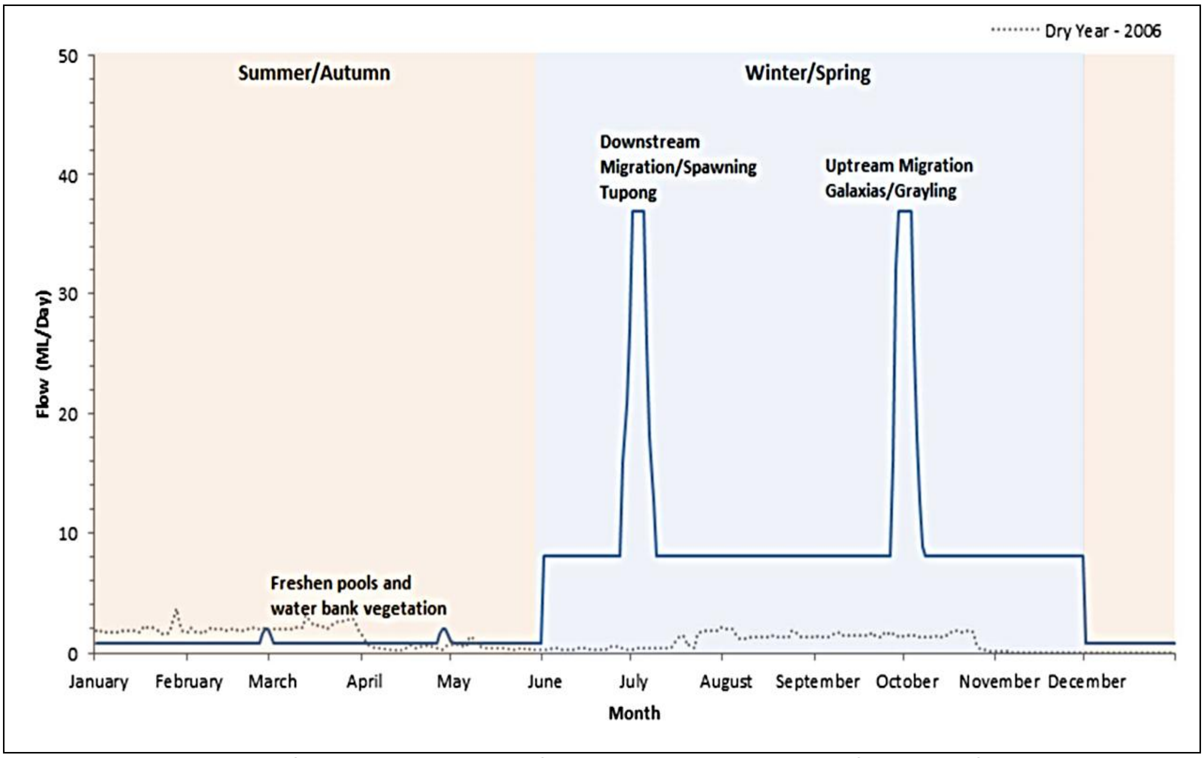


Figure 6.3. Environmental flow recommendations for Reach 1 in dry years. The flow series for the year 2006 is shown as an example of a year experiencing dry flow conditions.

Table 6.4. Environmental flow recommendations for Reach 2 – Moorabool River West Branch: Moorabool Reservoir to Lal Lal Reservoir.

Season	Flow	Hydrological objectives (Ecological objectives)	Wet/ average/ dry	Magnitude	Frequency and timing	Duration	Rise / fall*
Summer / Autumn (Dec–May)	Low flow	Maintain pool and riffle habitats for fish, macroinvertebrates, platypus and submerged aquatic vegetation (F1, F2, M1, V1, P1, P2, P3). Maintain water quality (W1).	Wet / Average	5 ML/Day	December to May	6 months	NA
			Dry	2.5 ML/Day	December to May	6 months	NA
	Fresh	Flush silt, and scour biofilms and algae from streambed (M1). Water fringing marginal zone vegetation (V2, V3). Allow fish and platypus movement through the reach and maintain access to habitat (F1).	Wet / Average	30 ML/Day	3 events	3 Days	2/0.7
			Dry	30 ML/Day	1 event every 2 to 3 years	3 days	2/0.7
Winter / Spring (Jun-Nov)	Low flow	Allow fish movement throughout the reach (F1). Maintain clear flow path and control intrusions by terrestrial vegetation (V1).	Wet / Average	5 ML/Day	June to November	6 months	NA
			Dry	2.5 ML/Day	June to November	6 months	NA
	Fresh	Allow fish and platypus movement through the reach and maintain access to habitat (F1). Flush silt, and scour biofilms and algae from streambed (M1) and transport of organic matter (W2). Promote growth and recruitment of native riparian vegetation including woody shrubs and promote strong vegetation zonation on the banks (V2, V3).	Wet / Average	40 ML/Day	3 events	3 Days	2/0.7
			Dry	40 ML/Day	3 events	3 Days	2/0.7
	High flow	Scour pools and maintain channel form and dimensions (G1). Inundate benches and inset floodplains (G2, V4).	Wet / Average	250 ML/Day	1 event every 2 years, preferably in Winter to avoid risks to platypus (no control over timing)	1-2 Days	2/0.7

* Recommended rates of Rise/Fall are provided as a factor of the previous days flow and have been determined based on assessment of daily flow data recorded at flow gauges downstream of all storages in the Moorabool River (SKM 2004b).

Table 6.5.Environmental flow recommendations for Reach 3a – Moorabool River West Branch: Lal Lal Reservoir to Moorabool River East Branch.

Season	Flow	Hydrological objectives (Ecological objectives)	Wet/ average/ dry	Magnitude	Frequency and timing	Duration	Rise / fall*
Summer / Autumn (Dec–May)	Low flow	Maintain pool and riffle habitats for fish, macroinvertebrates, platypus and submerged aquatic vegetation (F1, F2, M1, V1, P1, P2, P3). Maintain water quality (W1).	Wet / Average	10 ML/Day	December to May	6 months	NA
			Dry	5 ML/Day	December to May	6 months	NA
	Fresh	Flush silt, and scour biofilms and algae from streambed (M1). Water fringing marginal zone vegetation (V2, V3). Allow fish and platypus movement through the reach and maintain access to habitat (F1, F2). Trigger downstream spawning/migration of short-finned eel and grayling (F1).	Wet / Average	60 ML/Day	2 events, April/May (grayling) and January/February (short-finned eel)	5 Days	2/0.7
				30 ML/Day	1 event in February/March to water fringing vegetation	3 Days	2/0.7
			Dry	60 ML/Day	1 event every 2 to 3 years, April/May (grayling)	5 Days	2/0.7
Winter / Spring (Jun-Nov)	Low flow	Allow fish movement throughout the reach (F1, F2). Maintain clear flow path and control intrusions by terrestrial vegetation (V1).	Wet / Average	60 ML/Day Aspirational 10 ML/Day Achievable	June to November	6 months	NA
			Dry	60 ML/Day Aspirational 5 ML/Day Achievable	June to November	6 months	NA
	Fresh	Allow fish and platypus movement through the reach and maintain access to habitat (F1, F2). Trigger downstream spawning/migration of tupong. Upstream migration of galaxias and grayling (F1). Flush silt, and scour biofilms and algae from streambed (M1) and transport of organic matter (W2). Promote growth and recruitment of native riparian vegetation including woody shrubs and promote strong vegetation zonation on the banks (V2, V3)	Wet / Average	162 ML/Day Aspirational 80 ML/Day Achievable	1 event in June/July (tupong) and 2 events in September/October (galaxias and grayling)	10 Days Aspirational 5 Days Achievable	2/0.7
			Dry	162 ML/Day Aspirational 80 ML/Day Achievable	1 event in June/July (tupong) and 1 event in September/October (galaxias and grayling)	10 Days Aspirational 5 Days Achievable	2/0.7
	High flow	Scour pools and maintain channel form and dimensions (G1). Inundate benches and inset floodplains (G2, V4). Flushing of sediment to improve spawning sites (F2).	Wet / Average	500 ML/Day	1 event every 2 to 3 years, preferably in Winter to avoid risks to platypus (no control over timing)	1 to 2 Days	2/0.7

*Recommended rates of Rise/Fall are provided as a factor of the previous days flow and have been determined based on assessment of daily flow data recorded at flow gauges downstream of all storages in the Moorabool River (SKM 2004b).

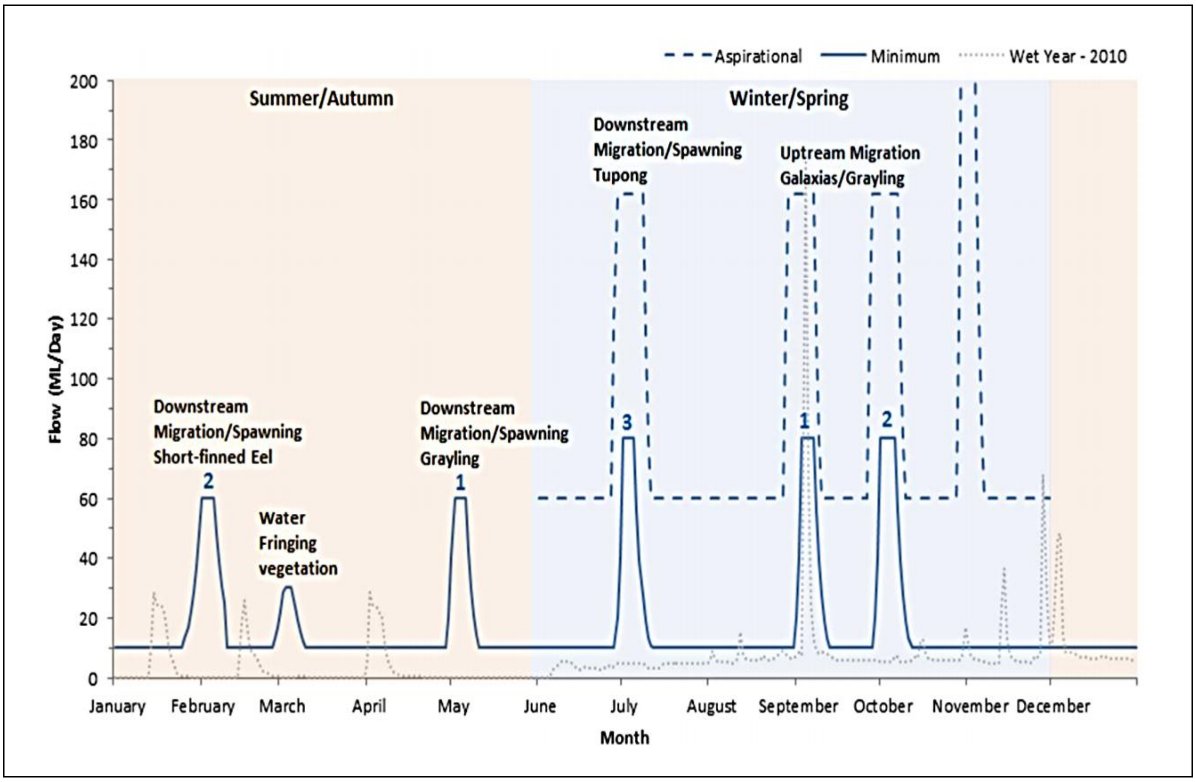


Figure 6.4. Environmental flow recommendations for Reach 3a in wet/average years. The flow series for the year 2010 is shown as an example of a year experiencing wet flow conditions. Note the high flow recommendation of 500 ML/Day extends beyond the range of the scale shown on this plot.

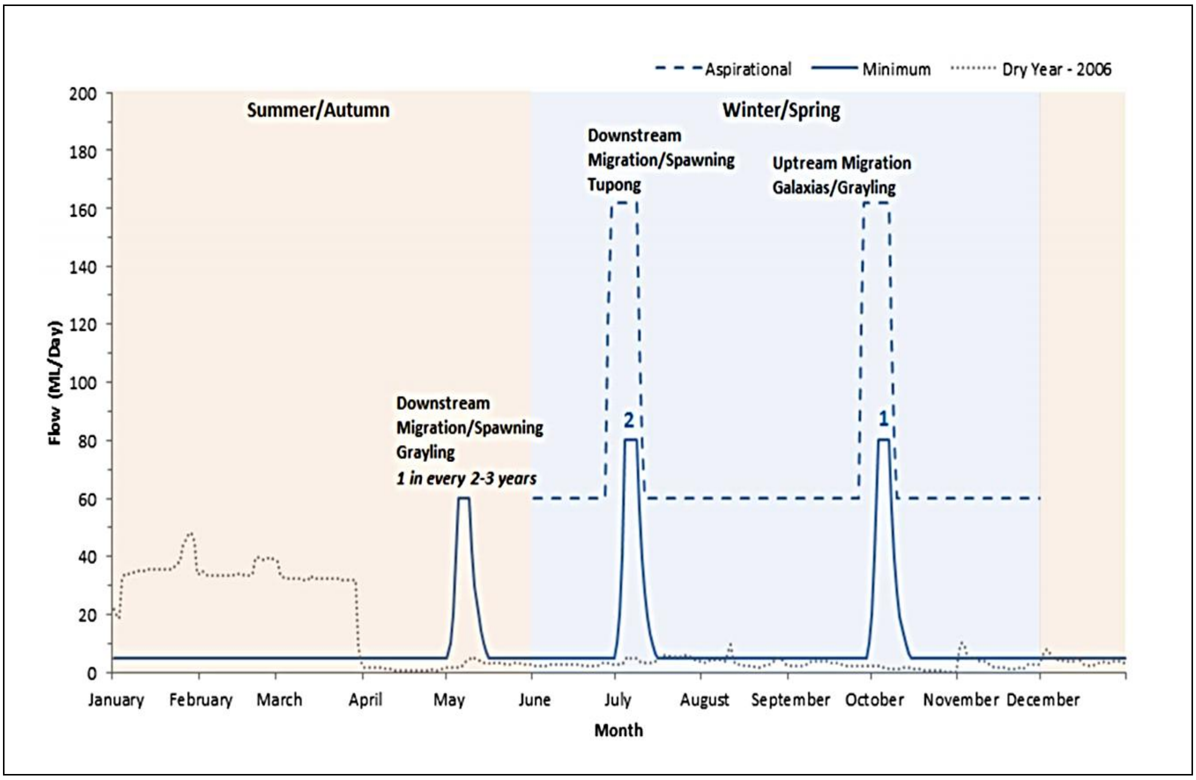


Figure 6.5. Environmental flow recommendations for Reach 3a for dry years. The flow series for the year 2006 is shown as an example of a year experiencing dry flow conditions.

Table 6.6. Environmental flow recommendations for Reach 3b – Moorabool River: Moorabool River to Sharps Rd, She Oaks

Season	Flow	Hydrological objectives (Ecological objectives)	Wet/ average/ dry	Magnitude	Frequency and timing	Duration	Rise / fall*
Summer / Autumn (Dec–May)	Low flow	Maintain pool and riffle habitats for fish, macroinvertebrates, platypus and submerged aquatic vegetation (F1, F2, M1, V1, P1, P2, P3). Maintain water quality (W1).	Wet / Average	20 ML/Day	December to May	6 months	NA
			Dry	10 ML/Day	December to May	6 months	NA
	Fresh	Flush silt, and scour biofilms and algae from streambed (M1). Water fringing marginal zone vegetation (V2, V3). Allow fish and platypus movement through the reach and maintain access to habitat (F1, F2). Trigger downstream spawning/migration of short-finned eel and grayling (F1).	Wet / Average	60 ML/Day	2 events, April/May (grayling) and January/February (short-finned eel)	5 Days	2/0.7
				30 ML/Day	1 event in February/March to water fringing vegetation	3 Days	2/0.7
			Dry	60 ML/Day	1 event every 2 to 3 years, April/May (grayling)	5 Days	2/0.7
		Freshen water quality when DO < 5 mg/L (W1)	Dry	30 ML/Day	1 event as required	3 Days	2/0.7
Winter / Spring (Jun-Nov)	Low flow	Allow fish movement throughout the reach (F1, F2). Maintain clear flow path and control intrusions by terrestrial vegetation (V1).	Wet / Average	86 ML/Day Aspirational 20 ML/Day Achievable	June to November	6 months	NA
			Dry	86 ML/Day Aspirational 10 ML/Day Achievable	June to November	6 months	NA
	Fresh	Allow fish and platypus movement through the reach and maintain access to habitat (F1, F2). Trigger downstream spawning/migration of tupong. Upstream migration of galaxias and grayling (F1). Flush silt, and scour biofilms and algae from streambed (M1) and transport of organic matter (W2). Promote growth and recruitment of native riparian vegetation including woody shrubs and promote strong vegetation zonation on the banks (V2, V3)	Wet / Average	162 ML/Day Aspirational 80 ML/Day Achievable	1 event in June/July (tupong) and 2 events in September/October (galaxias and grayling)	10 Days Aspirational 5 Days Achievable	2/0.7
			Dry	162 ML/Day Aspirational 80 ML/Day Achievable	1 event in June/July (tupong) and 1 event in September/October (galaxias and grayling)	10 Days Aspirational 5 Days Achievable	2/0.7
	High flow	Scour pools and maintain channel form and dimensions (G1). Inundate benches and inset floodplains (G2, V4). Flushing of sediment to improve spawning sites (F2).	Wet / Average	1000 ML/Day	1 event every 2 to 3 years, preferably in Winter to avoid risks to platypus	1 to 2 Days	2/0.7

*Recommended rates of Rise/Fall are provided as a factor of the previous days flow and have been determined based on assessment of daily flow data recorded at flow gauges downstream of all storages in the Moorabool River (SKM 2004b).

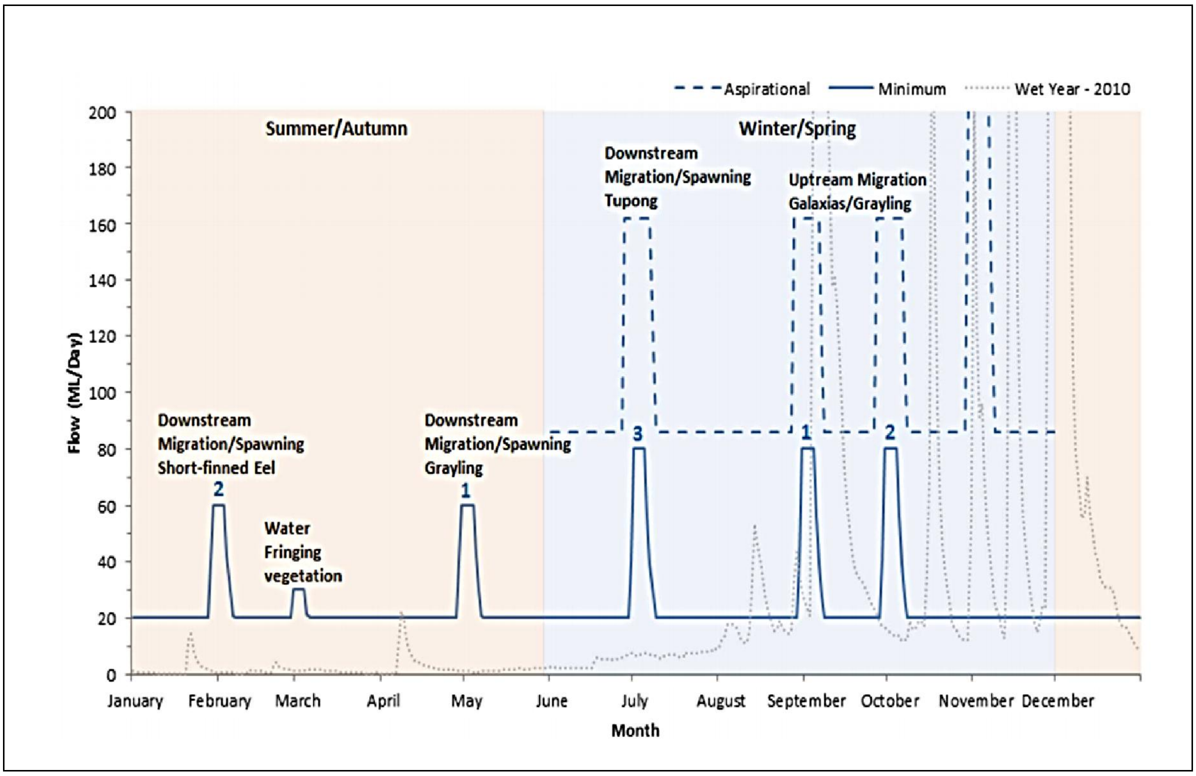


Figure 6.6. Environmental flow recommendations for Reach 3b in wet years and prioritisation of fresh flow events. The flow series for the year 2010 is shown as an example of a year experiencing wet flow conditions.

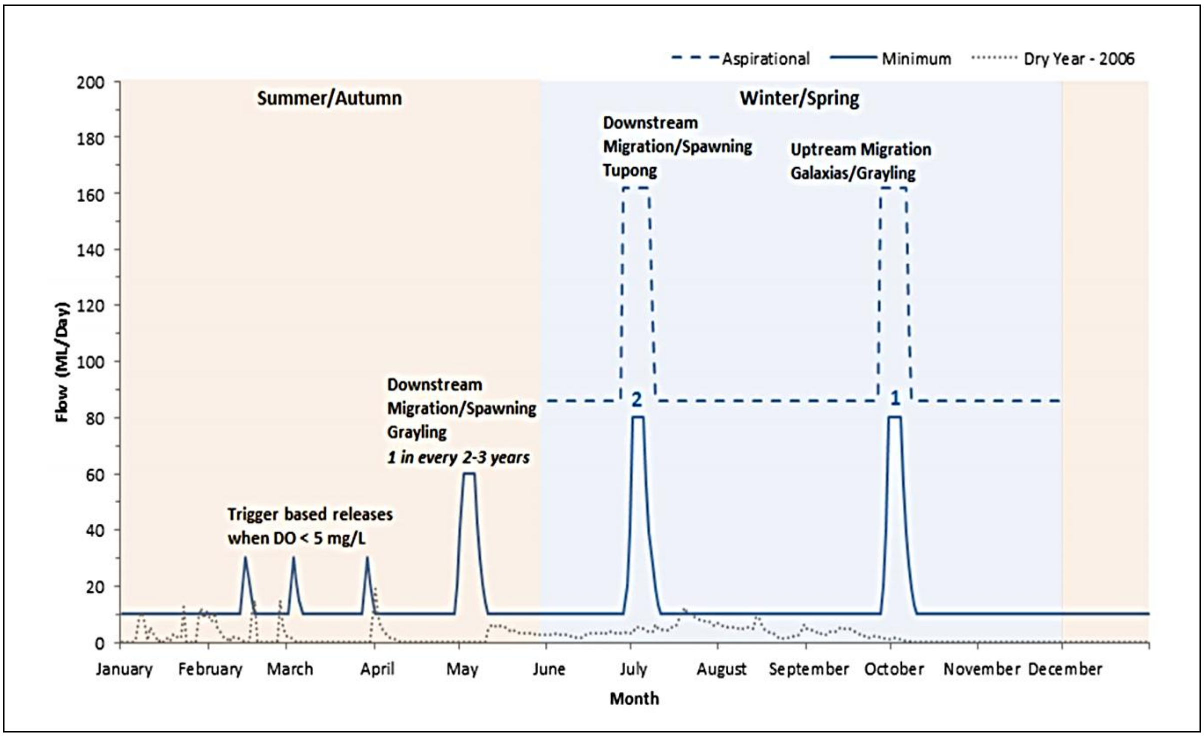


Figure 6.7. Environmental flow recommendations for Reach 3b in dry years and prioritisation of fresh flow events. The flow series for the year 2006 is shown as an example of a year experiencing dry flow conditions.

Table 6.7. Environmental flow recommendations for Reach 4 – Moorabool River: Sharps Rd, She Oaks to Barwon River

Season	Flow	Hydrological objectives (Ecological objectives)	Wet/ average/ dry	Magnitude	Frequency and timing	Duration	Rise / fall*
Summer / Autumn (Dec–May)	Low flow	Maintain pool and riffle habitats for fish, macroinvertebrates, platypus and submerged aquatic vegetation (F1, F2, M1, V1, P1, P2, P3). Maintain water quality (W1).	Wet / Average	20 ML/Day Achievable	December to May	6 months	NA
			Dry	10 ML/Day Achievable	December to May	6 months	NA
	Fresh	Flush silt, and scour biofilms and algae from streambed (M1). Water fringing marginal zone vegetation (V2, V3). Allow fish and platypus movement through the reach and maintain access to habitat (F1, F2). Trigger downstream spawning/migration of short-finned eel and grayling (F1).	Wet / Average	60 ML/Day Achievable	2 events, April/May (grayling) and January/February (short-finned eel)	5 Days	2/0.7
				30 ML/Day Achievable	1 event in February/March to water fringing vegetation	3 Days	2/0.7
			Dry	60 ML/Day Achievable	1 event every 2 to 3 years, April/May (grayling)	5 Days	2/0.7
		Freshen water quality when DO < 5 mg/L (W1)	Dry	30 ML/Day Achievable	1 event as required	3 Days	2/0.7
Winter / Spring (Jun-Nov)	Low flow	Allow fish movement throughout the reach (F1, F2). Maintain clear flow path and control intrusions by terrestrial vegetation (V1).	Wet / Average	86 ML/Day Aspirational 20 ML/Day Achievable	June to November	6 months	NA
			Dry	86 ML/Day Aspirational 10 ML/Day Achievable	June to November	6 months	NA
	Fresh	Allow fish and platypus movement through the reach and maintain access to habitat (F1, F2). Trigger downstream spawning/migration of tupong. Upstream migration of galaxias and grayling (F1). Flush silt, and scour biofilms and algae from streambed (M1) and transport of organic matter (W2). Promote growth and recruitment of native riparian vegetation including woody shrubs and promote strong vegetation zonation on the banks (V2, V3)	Wet / Average	162 ML/Day Aspirational 80 ML/Day Achievable	1 event in June/July (tupong) and 2 events in September/October (galaxias and grayling)	10 Days Aspirational 5 Days Achievable	2/0.7
			Dry	162 ML/Day Aspirational 80 ML/Day Achievable	1 event in June/July (tupong) and 1 event in September/October (galaxias and grayling)	10 Days Aspirational 5 Days Achievable	2/0.7
	High flow	Scour pools and maintain channel form and dimensions (G1). Inundate benches and inset floodplains (G2, V4). Flushing of sediment to improve spawning sites (F2).	Wet / Average	3000 ML/Day	1 event every 2 to 3 years, preferably in Winter to avoid risks to platypus	1 to 2 Days	2/0.7

*Recommended rates of Rise/Fall are provided as a factor of the previous days flow and have been determined based on assessment of daily flow data recorded at flow gauges downstream of all storages in the Moorabool River (SKM 2004b).

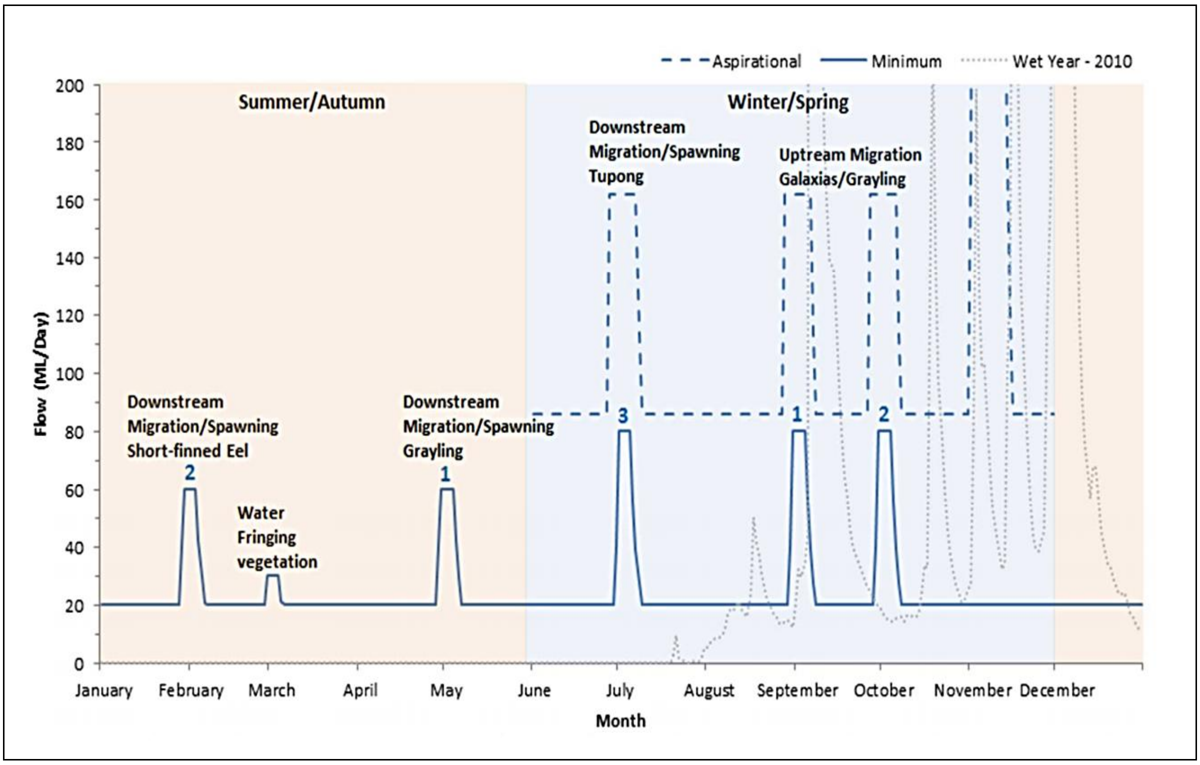


Figure 6.8. Environmental flow recommendations for Reach 4 wet years and prioritisation of fresh flow events. The flow series for the year 2010 is shown as an example of a year experiencing wet flow conditions.

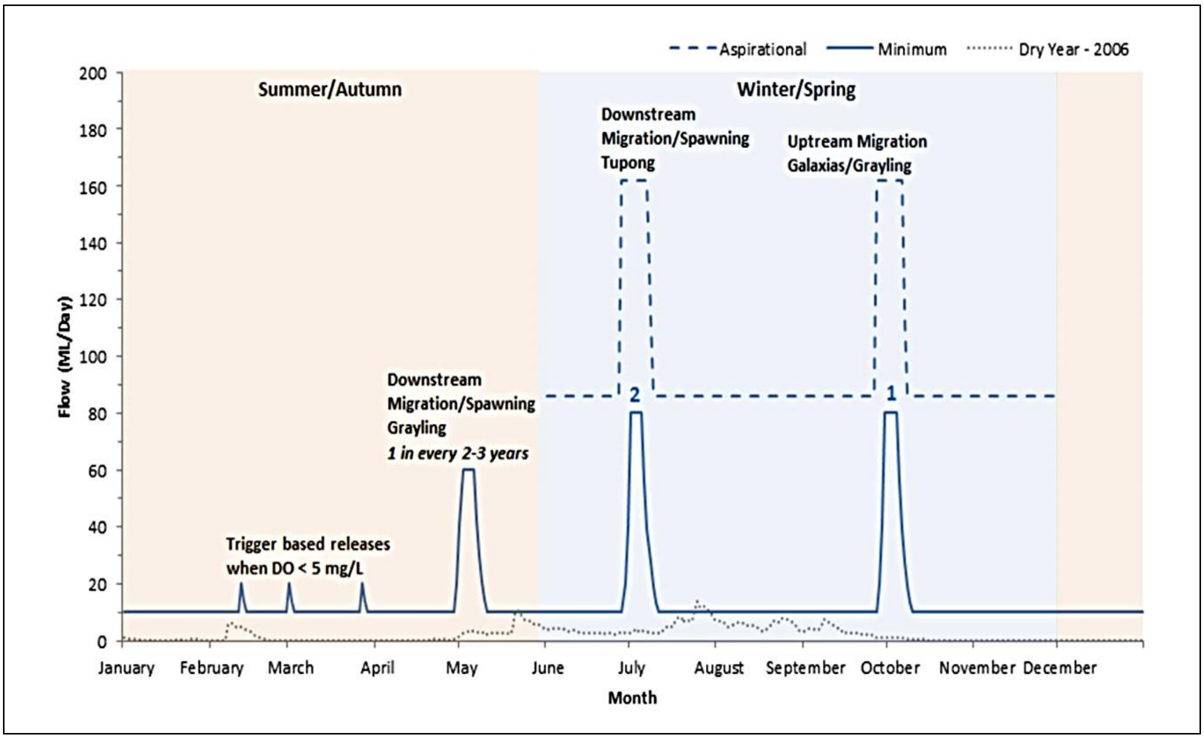


Figure 6.9. Updated environmental flow recommendations for Reach 4 a dry year and prioritisation of freshes. The flow series for the year 2006 is shown as an example of a year experiencing dry flow conditions**.**

7 Managing risks to achieving objectives

7.1 Risk assessment

The risk assessment in Table 7.1 identifies the level of risk posed by various threats to the water-dependent ecological values of the Moorabool River. Threats to the water-dependent ecological values may have a direct impact on achieving the objectives of the EWMP.

The risk assessment identifies the avenues available to manage threats to the rivers ecological values. A number of threats can be managed in accordance with the Corangamite CMAs responsibilities under the Moorabool River Environmental Entitlement 2010. Although it is also important to note that:

- Not all threats can be managed by the EWMP and the Corangamite CMA environmental watering program.
- The threats that cannot be dealt with through the environmental watering program require a combination of external parties and mechanisms to reduce the residual risk (as detailed in management measure column).
- Some projects separate to the environmental watering program, but are still managed by the Corangamite CMA, can assist as management measures i.e. biodiversity tender programs.

Table 7.1. Risk matrix

		Consequence		
		Major	***Moderate***	***Minor***
Likelihood	***Certain***	High	High	Moderate
	Possible	High	Moderate	Low
	Unlikely	Moderate	Low	Low

Results from the Moorabool Rivers qualitative risk assessment are shown in Table 7.2, containing risk ratings and estimated residual risks following the implementation of successful management measures. A process is identified to address threats that are outside the scope of the EWMP.

The Moorabool Stakeholder Advisory Committee's role in developing risk assessment

The Moorabool Stakeholder Advisory Committee played a key role in identifying threats to the Moorabool River and assisting in the identification of management measures. Members of the Moorabool Advisory Stakeholder Committee (MSAC) attended project meetings in mid-2015 and were asked to describe the environmental threats impacting the river. The MSAC highlighted a broad range of threats that impact on the ability to achieve the objectives of the environmental watering program and the significance of the threats placed on the Moorabool River. A review process has been identified in Chapter 11 to ensure management measures are reviewed, and an adaptive management approach is applied to achieve the best outcomes for the river.

Table 7.2. Moorabool River qualitative risk assessment –*managing risks to achieving objectives*

Threat #	Threat detail	Likelihood	Consequence	Risk	Management measure	Residual risk	MSAC review
1	Not enough water available in the environmental entitlement to deliver flow components in reaches 3a, 3b, and 4.	Certain	Major	High	-Investigate opportunities to increase environmental allocation. CCMA to progress conversations with the relevant government departments and water authorities to increase the current environmental entitlement volume. - MSAC to provide input, via informal or formal means to the upcoming DELWP Living Geelong Strategy to link water augmentation options to water recovery	high	2016
2	Insufficient flow in reaches 1 and 2 of the Moorabool River to support ecological values. Note – there are currently limited ecological values in this reach as compared to reach 3a, 3b, and 4.	Certain	Moderate	Moderate	CCMA to investigate opportunities to increase passing flow rules for Bostock and/or Moorabool reservoirs. Consider potential for environmental entitlements from these reservoirs.	Moderate	2016
3	Surface water extraction (Dams, diversions/pumping) remove environmental releases from the river. Groundwater extraction reduce base flow in river and impact ecological values	Certain	Major	High	-Investigate opportunities to provide feedback/recommendations on relevant SRW regulatory framework to support protection of river flows. -Protect winter flows by providing input into SRW Local Area Management Plans (LAMPs), and review the 16ml/d extraction rule threshold to ensure winter season releases are protected. -D&S extraction is banned by SRW over summer season and low flow is protected. Highlight need for increased SRW compliance activities. -Investigate LAMPs opportunities to establish groundwater restrictions in the Bungaree area to reduce base flow impacts.	Moderate	2016

Threat #	Threat detail	Likelihood	Consequence	Risk	Management measure	Residual risk	MSAC review
4	Passing flow rules in CHW Bulk Entitlement do not adequately protect waterway health	Possible	Moderate	Moderate	-Investigate opportunities within Lal Lal bulk entitlements to hold-back daily passing flows and bank them during low risk periods (wet seasonal conditions) so that passing flows can used to protect river health when river is under stress ie summer period or dry seasonal conditions.	Low	2016
5	Climate change reduces stream flow and increases risk of potential loss of flow dependent species and communities	Certain	Moderate*	High	-Ensure Seasonal Watering Proposals adequately plan environmental flows in consideration of a drying climate and give consideration to reduced stream flow implications. -CCMA to progress conversations with the relevant government departments and water authorities to increase the current environmental entitlement volume. *- refer to complimentary works table 9.2*	High	2016
6	illegal native vegetation removal creates a loss of habitat and impacts waterway health	Certain	Moderate	Moderate	Continue Council and DELWP compliance activities to uphold native vegetation regulations under the Planning & Environment Act and Forestry Act	Moderate	2016
7	land use practices (sand quarries, gold sluicing, cropping and intensive grazing) cause Erosion and sedimentation i.e. sand slugs	Certain	Moderate	Moderate	-Relevant Authorities to continue regulatory and compliance activities. *- refer to complimentary works table 9.2*	Moderate	2016
8	Loss of baseflows to Batesford Quarry. Loss of habitat, connectivity and river function created by 2km river diversion channel around quarry	Certain	Major	High	-Facilitate conversations with Adelaide Brighton about future remediation priorities/works – actively seek input/contribution to rehabilitation plans.	Moderate	2016
9	Illegal four-wheel driving and motorbike riding	Probable	Minor	Low	-Relevant authorities to continue regulatory	Low	2016

Threat #	Threat detail	Likelihood	Consequence	Risk	Management measure	Residual risk	MSAC review
	activities in riparian zone				and compliance activities. -- *refer to complimentary works table 9.2*		
10	Introduced flora and fauna (willows, blackberry, gorse and aggressive exotic fish species)	Certain	Moderate	Moderate	-Undertake weed removal as part of Corangamite Waterway Strategy and biodiversity tender/river health programs, targeting high priority areas -options to introduce carp virus, when available -- *refer to complimentary works table 9.2*	Low	2016
11	Rubbish (tyres) restricting flow, creating river barriers and spoiling amenity	Possible	Minor	Low	-Promote the need for private companies and regulatory authorities to ensure compliance with legislation - *refer to complimentary works table 9.2*	Low	2016
12	High flow releases drowning juvenile platypus	Possible	Moderate	Moderate	Ensure timing and volume of delivered flows does not coincide with significant rainfall events in the river system.	Low	2016
13	Flow releases causing personal injury to river users	Unlikely	Major	Moderate	-Delivered flows are low in volume and velocity with a sufficient rise/fall to ensure gradual change in water level. -Detailed risk assessment undertaken prior to each release event. This risk assessment will consider catchment conditions, the seven day weather forecast and the level of communication required. -media releases in local papers if releases are likely to substantially alter flow height	Low	2016
14	Current recommendations on environmental flows are inaccurate	Possible	Moderate	Moderate	Flow recommendations are based on the best possible science and a monitoring program is in place to identify if ecological objectives are	Low	2016

Threat #	Threat detail	Likelihood	Consequence	Risk	Management measure	Residual risk	MSAC review
					not being achieved.		
15	Resource Manager cannot deliver required volume or flow rate (outlet capacity constraints)	Certain	Moderate	High	Release environmental flows in conjunction with natural rainfall events, releases for consumptive use or when passing flows increase owing to rainfall.	High	2016
16	Releases cause water quality issues (e.g. blackwater, low DO, mobilisation of saline pools etc)	Possible	Moderate	Moderate	Water quality monitoring is in place to measure effects of releases.	Low	2016
17	Releases improve habitat conditions for non-native species (e.g. gambusia, carp)	Possible	Moderate	Moderate	Investigate opportunities to undertake future aquatic fish surveys and compare abundance and distribution using SRA protocols used in 2014 fish survey	Low	2016
18	Environmental releases cause flooding of private land, public infrastructure or Crown land	Unlikely	Major	Moderate	Media release before any summer or winter fresh events, monitor water levels. If a flood watch is issued by the Bureau of Meteorology, all environmental water releases will be stopped until warning has been removed and it is safe to resume.	Low	2016
19	Fish passage and connectivity in the lower reaches is compromised due to in-stream weirs, resulting in an inability to achieve ecological objectives	Certain	Moderate	High	-CCMA to conduct a review of barriers to connectivity within the Moorabool River system. Subsequent removal of priority weirs where possible. -Facilitate conversations with Adelaide Brighton about future remediation priorities/works – actively seek input/contribution to rehabilitation plans. *Refer to Treat 8 measures.*	High	2016
20	Increase in number of licenced and unlicensed farm dams reduced inflows, streamflow and baseflow	Certain	Major	High	-Promote the need to undertake a hydrological analysis to improve knowledge of the impacts of farm dams	High	2016

Threat #	Threat detail	Likelihood	Consequence	Risk	Management measure	Residual risk	MSAC review
					-Investigate options to cap total farm dam volumes in the Moorabool Catchment through collaborative work with DELWP.		
21	Urban Growth –Fyansford & Batesford Western Growth Corridor degrade riparian vegetation and reduce water quality.	Possible	Moderate	Moderate	Facilitate conversations with COGG regarding river public-use corridor to protect riparian zone biodiversity to ensure environmental water and water quality are protected. Investigate opportunities to provide feedback into the Western Further Investigation Area.	Moderate	2016
22	Riparian Zone degradation –loss of remnant vegetation/weeds/nitrification and stock access	Certain	Moderate	Moderate	Fencing and reinstatement of native vegetation of riparian zone and including stock exclusion or modified grazing regime in Riparian Management Agreements with landholders (currently being undertaken in line with the Corangamite Waterway Strategy). *- refer to complimentary works table 9.2*	Moderate	2016
23	Blue-green algae bloom in reservoir resulting is cessation of environmental flows	Possible	Moderate	Moderate	Environmental water delivery will be discontinued if it is considered that this will cause a blue-green algae event in the river.	Low	2016
24	Environmental water account is overdrawn	Unlikely	Moderate	Low	-Environmental release volumes are tracked on a daily bases when a release is in progress. CCMA release requests are cross checked against CHW figures. If accounting is not accurate request a review of VEWH Operating Arrangements.	Low	2016
25	Unable to provide evidence in meeting ecological objective	Certain	Moderate	Moderate	-Ongoing evaluation of monitoring results and implementation of recommendations. --Investigate opportunities to undertake future aquatic fish surveys and compare abundance and distribution using SRA protocols used in	Moderate	2016

Threat #	Threat detail	Likelihood	Consequence	Risk	Management measure	Residual risk	MSAC review
					2014 fish survey.		
26	Key stakeholders not supportive of environmental water release	Possible	Moderate	Moderate	-Community meeting prior to developing seasonal watering proposals. -Instate the Moorabool River Stakeholder Advisory Committee for the longer-term (i.e., post-EWMP development)	Low	2016
27	Transfer of Barwon Waters *Lal Lal Bulk Entitlement* to Central Highlands Water	Possible	Major	High	-Liaise with BW, CHW and DELWP to ensure this threat is understood and communication is maintained on the issue. Any water transfer option considers the associated environmental impacts to Reach 3a & 3b (Lal Lal to Sheoks offtake). -Identify the need for an increased water allocation to the E.E, if the BE is amended so that this risk is mitigated	Low	2016

*Climate change has only been given a ‘moderate’ consequence rating because the EWMP only plans over 10-year timescale, rather than a long-term time scale.

8 Environmental water delivery infrastructure

Environmental water delivery within the Moorabool River system is from Lal Lal Reservoir, where the environmental entitlement is held, and is limited by a number of constraints, both physical (weirs and reservoirs) as well as operational. A water quality gauging station is located at Coopers Crossing in reach 3b and informs environmental water decision making.

8.1 Constraints

Physical constraints

Reaches 1 and 2 – currently there is no environmental entitlements held in any storage along these two reaches of the Moorabool River and as such, the recommended flows detailed in this document cannot be managed. Flow within these reaches is dependent on passing flows (under the relevant Water Authorities bulk entitlement) from Bostock (Reach 1) or Moorabool (Reach 2) reservoirs, surface and groundwater inflows and in wetter years, any spilling over the reservoir spillways.

Operational constraints

The main operation constraint that impacts the ability to deliver water out of the environmental entitlement from The Lal Lal reservoir is the outlet capacity. The outlet can deliver a maximum flow rate of 146ML/day which in turn restricts the ability to fully deliver Winter Fresh flows of 80 ML/day to Reaches 3a, 3b and 4. Therefore the ability to achieve this flow component is reliant upon Lal Lal reservoir filling to capacity and subsequently spilling over the spillway.

8.2 Irrigation modernisation

Urban growth in Ballarat and greater Geelong (Bannockburn and Western Growth Investigation Area) places greater water resource pressure on regional water supplies in the region. The Moorabool River currently provides potable water to meet domestic water demands. DELWP have recently developed a Living Ballarat Strategy which looks at improvements to water supply and sustainability in the region through a number of recommended water augmentation projects and recommended policy parameters. This strategy highlights the value of irrigation modernisation in the Moorabool catchment and the environmental flow benefits for regional rivers like the Moorabool. Regional water augmentation projects present infrastructure modernisation and present opportunities to reduce potable water demand pressure on the Moorabool River. The recent installation of the Melbourne-Geelong water pipeline has increased water security for the Geelong region and has the potential to alleviate flow stress on the Moorabool, depending management needs of the water authorities potable water supply.

9 Demonstrating outcomes

The ability to meet the EWMP goal and *improve* the Moorabool Rivers flow-dependent ecological values requires two things, water recovery and ecological responses monitoring projects to determine the effectiveness of environmental flows and compliance with targets. Monitoring projects provide the ability to:

- Improve the management of environmental water
- Modify and adapt environmental water releases to better manage ecological values. Identify trends and risks early to allow adaptive management processes
- Demonstrate the value and achievements of environmental watering to the broader community and government.

9.1 Monitoring priorities

Monitoring is a fundamental requirement to be able to measure if ecological objectives have been met. Therefore, implementing ecological response monitoring programs is needed to assess the outcomes of the environmental watering program and provide the basis for adjusting and improving environmental water management. Ecological response monitoring projects are listed below in Table 9.1 and have been separated into the six ecological categories, in accordance with the identified ecological objectives.

Table 9.1: Ecological response monitoring projects proposed that identify if ecological objectives are being met

Monitoring category **(EWMP ecological objective)**	**Ecological response monitoring project**	**Priority**
Fish	1. Aquatic sampling project that replicates the SRA monitoring protocols used in the 2014 fish survey. Determine if species diversity and abundance has changed at the 21 identified survey sites. 2. Fish movement studies are required to develop a greater understanding of fish movement along the Moorabool River. This is needed to confirm fish are moving past barriers and to provide a greater understanding of the specific magnitude and timing of flows required to facilitate movement for different fish species. While flow freshes have been recommended to trigger upstream migration of juvenile diadromous fish, our understanding of the influence of flow on the upstream migration of these diadromous fishes is limited at present. Further information is also required on where along the Moorabool River the fish are moving to and what habitat they are using.	1
Macroinvertebrates	1. Continue Waterwatch monitoring program at 9 identified sites and determine if data collection could be increased or better used to inform environmental flow delivery 2. Macroinvertebrate study for Reach 3 & 4 of the Moorabool River to determine if ecological objectives are being met and changes to watering	3
Vegetation	1. Assessment of flow-dependent vegetation communities in the Moorabool River to establish a baseline. 2. Targeted monitoring following establishment of baseline data that includes an assessment of indicator species insitu to determine if ecological	1

	objectives are being met.	
Platypus	It is recommended that a database should be established to consistently record Platypus and Rakali sightings by landholders or management agency staff, as this is the most cost-effective method to identify where theses species occur. Determine if objectives P1, P2 or P3 are being met	3
Geomorphology	Investigate hydrogeomorphology change in the Moorabool catchment to determine change since the 2003 and 2014 FLOWS Studies.	3
Water quality	1. Waterwatch monitoring program at 9 identified sites and determine if data collection could be increased or better used to inform environmental flow delivery 2. Water quality compliance monitoring at Coopers Crossing gauging station (reach 3a). Flow monitoring at Morrisons (reach 3b) and Batesford (reach 4) gauging stations to inform e.flow releases and water quality trends. 3. Water quality monitoring at 8 identified sites in reaches 3 & 4 during high risk periods. This program is conducted during the critical water quality risk period during summer/autumn and a week before and after one summer fresh and one winter fresh each year (if applicable). Helps determine trends, and inform the need to implement 'trigger based fresh' events to maintain minimum water quality parameters for reliant biota	1

9.2 Complementary works

There are a range of management strategies and actions needed when considering environmental flow management. It is rare that all of the environmental issues and threats within a catchment can be resolved by only providing an appropriate flow regime. In most catchments, other management actions and works need to be implemented in combination with flow management to meet the stated environmental flow objectives.

Land use, particularly clearing and uncontrolled stock access is contributing to degradation of riparian vegetation. The Corangamite CMA Regional Waterway Strategy identifies a number of management activities that are focused on protecting the stream-side zone along the Moorabool River. These include installation of riparian fencing, establishment of native indigenous vegetation, weed control and the establishment of stewardship/management agreements.

Table 9.2 Complementary works table

Complementary works & measures	Management details	How will works improve e.water delivery?
Revegetation of riparian zone	connecting riparian corridors and river shading	Improve water quality and ecological process, including providing food source for macroinvertebrates Increase river resilience, flow resilience and climate change resilience
Riparian fencing	Bank stabilisation and reduced stock access and erosion and pugging. Allows natural recruitment of native vegetation. Reduces 4wd and motorbike access	Reduced turbidity, improved water quality.
Weed removal (willows, blackberry, gorse etc)	Bank stabilisation and allows natural recruitment of native vegetation due to reduced competition	Improve water quality and ecological process, including providing food source for macroinvertebrates
Control feral animals (foxes, rabbits and cats)	Reduced predation on native fauna such as birds, water rats and platypus	Improves the ability of e flows to support native fauna ie birds, water rats, platypus

10 Consultation

The Moorabool Stakeholder Advisory Committee (MSAC) was established by the Corangamite CMA in 2014 to support the development of the Moorabool Environmental Water Management Plan (this document) and the Moorabool Flows Study Update.

The MSAC had a key role in determining the ecological values, objectives, threats, and opportunities for the Moorabool River. Furthermore, the committee helped set the direction of the EWMP by developing a goal and setting aspirations for the 10-year duration of the document.

The MSAC is a passionate and dedicated group of individuals, groups and government representatives that have a broad combination of skills including technical knowledge, historical information, government policy and understanding community values.

The MSAC had three formal meetings between April and June 2014 and a field-based meeting in 2014. The committee has been involved in reviewing documents and providing feedback via email correspondence. The Corangamite CMA is keen to support the continuation of the MSAC to ensure there is a formal community representation for the Corangamite CMA's environmental watering program. In particular, the MSAC will have a role in reviewing this document and annual Seasonal Watering Proposals. Please refer to Chapter 11 Document Review.

Current committee members include:

- Stuart McCallum (PALM)
- Cameron Steele (PALM, EV)
- Ian Penna (adjoining landholder, PALM)
- Tony Woolford (Friends of Fyansford)
- Barbara Baird (community member)
- Angus Ramsay (SRW)
- Elissa Ashton-Smith / Felicity Spears (GL)
- Jared Scott (BW)
- Pat Russell (CHW)
- Chloe Wiesenfeld (VEWH)
- Wayne McLaren (CCMA)
- Jayden Woolley (CCMA)
- Rob Bone (CCMA)
- Saul Vermeeren (CCMA)

11 EWMP document review

The Moorabool Environmental Water Management Plan will be reviewed as required, using the MERI (Monitoring, Evaluation, Reporting & Improvement) process. Document review will be considered prior developing the annual Moorabool River Seasonal Watering Proposal.

The Corangamite CMA will implement a three-part review process, which will involve:

1. Internal document review, including policy, science and operational changes
2. Determine if there is a need to engage the Moorabool Stakeholder Advisory Committee (MSAC) to review the document. Or if the MSAC requests a review, implement step 3
3. Engage the MSAC to undertake a document review.

Key areas to review include Chapters 7, 9 and 12. Consideration also needs to be given to the long-term achievement of the EWMPs aspirations, including the water recovery, river health and improved resilience categories (detailed in *Aspirations of the Moorabool Stakeholder Advisory Committee*). On-ground work delivery will be reviewed as part of the independent MERI process for the Regional Catchment Strategy and Corangamite Waterway Strategy.

12 Knowledge gaps

Understanding knowledge gaps is an important part of managing risks associated with environmental water delivery. The following list highlights knowledge gaps in the Moorabool River system and projects to improve knowledge and consequently improve the environmental watering program. The projects have been prioritised by the CCMA and the relevant funding provider has been highlighted.

Please note these projects have not been committed to by the CMA or external funding providers. Rather, this list represents potential projects that could improve knowledge for managers and the community.

Project alignment to eco objective category	Knowledge gaps and project recommendation	Project priority	Responsible authority	Potential funding provider
Fish	Assessment of fish barriers Further understanding is required on the condition of natural and artificial barriers along the Moorabool River, the extent to which they pose a barrier to fish migration and what additional works are required to improve fish passage. Clearly, She Oaks Weir is the largest barrier impacting on fish movement and major works would be needed to provide fish passage. There are also a number of smaller barriers downstream (SKM 2004a). The Corangamite CMA in their Waterway Management Strategy (Corangamite CMA 2014) have committed to undertake an assessment of fish barriers in the Barwon and Moorabool catchments. Stage 1 review has been funded Stage 2 implementation plan will be developed in 2016	1	CCMA	DELWP *-technical and Works & Measures*
Platypus	Identification of habitat refuges To assist platypus survival in future severe drought periods, it is recommended that substantial pools that are likely to serve as important refuges for platypus during natural cease-to-flow events should be identified, mapped and managed appropriately (e.g. by fencing out livestock). It is possible that the best (or only) reasonably drought-proof pool in some parts of Reach 4 may be associated with an on-stream weir. If so, consideration should be given to installing a mechanism to facilitate fish passage around or over the weir, as opposed to removing the weir entirely.	1	CCMA	VEWH *-technical*

Fish, macroinvertebrates vegetation, water quality, geomorphology	Investigate water movement around Batesford Quarry Seepage and losses of stream flow into Batesford Quarry is an ongoing issue, which has the potential to impact on the connectivity of flows and fish passage. Options to address this seepage losses should be further investigated (discharge at upstream site). Degradation of concrete channel lining works has also led to the creation of potential barriers for fish and Platypus movement. The spurs found on the ankles of male Platypus (used to establish dominance when competing for territories and mates) are likely to be abraded in a very untimely manner if animals have to travel repeatedly along a concrete-lined channel. Further investigations are required to assess the condition of the river in this section, the nature of instability issues and options to improve the stability of the channel and habitat areas for aquatic organisms.	2	CCMA, Adelaide Brighton, DELWP	To be determined
Geomorphology	Investigate sand slugs The number, extent and mobility of sand slugs in the Moorabool Catchment need to be inventoried, and the potential threats that these pose to instream habitat needs to be assessed. Sand slugs dramatically simplify channel morphology, replacing complex structure and substrate with flat sheets of sand and gravel. Pools are filled in, and habitat is lost (Rutherfurd et al. 2000). Geomorphological changes can also impact other bulk entitlement holders and reservoir managers.	3	CCMA, CHW, BW	To be determined
Water quality	Water quality monitoring station It is recommended that additional water quality monitoring stations are installed (in addition to Coopers) in the lower sections of Reach 4 before confluence with the Barwon River and Reach 1 to confirm that recommended flow rates at the FLOWS assessment site do meet the minimum flow depths and acceptable water quality conditions further downstream.	1	CCMA	VEWH/ DELWP *-works and measures*

Fish, macroinvertebrates vegetation, water quality, geomorphology	Groundwater and Surface Water Interactions Further investigation and monitoring is needed of groundwater and surface water interactions in Reaches 1 to 4 to quantify the contribution of groundwater to low flow and freshes. This should include a specific assessment of Reach 4 interactions with Batesford Quarry, and result in an understanding of Groundwater Dependant Ecosystems across reaches. This may require the installation of additional bore holes adjacent to the river to provide a greater understanding of the influence of fluctuations in groundwater levels on surface water.	2	CCMA	VEW *-technical*
Vegetation	1. Aquatic and terrestrial ecological vegetation mapping. Including extent and condition assessments, threats and opportunities. Identification of high priority biodiversity corridors and habitat links in reaches 1, 2,3,4 and also connectivity to the Barwon and Lwr Barwon Wetlands and Ocean. 2. Photo Point Monitoring –Fluker Posts Defined photo monitoring points to increase community engagement with flows and help determine vegetation and structural change at identified sites over a period of time.	1	CCMA, research institutes, DEWLP (EVC Mapping/Natur e Print updates etc)	VEWH *-technical*
Fish, macroinvertebrates vegetation, water quality, geomorphology	Managing for Climate Change Changes to biota in response to climate change and understanding how to build resilience in ecological values to cope with a changing climate. Include concise and realistic management actions for waterway and land managers.	2	CCMA, research institutes,	VEWH, DELWP *-technical*

13 References

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14 Abbreviations and acronyms

APC Australian Platypus Conservancy

ARI Arthur Rylah Institute for Environmental Research

AUSRIVAS Australian River Assessment System

BW Barwon Water

CMA Catchment Management Authority

CHW Central Highlands Water

DELWP Department of Environment, Land, Water and Planning

DEDJTR Department of Economic Development, Jobs, Transport & Resources

EC Electrical Conductivity

EV Environment Victoria

EPA Environmental Protection Authority

EWMP Environmental Water Management Plan

EPBC Environmental Protection and Biodiversity Conservation Act 2000

EFTP Environmental Flow Technical Panel

EVC Ecological Vegetation Class

FFG Flora and Fauna Guarantee Act 1988

ISC Index of Stream Condition

MSAC Moorabool Stakeholder Advisory Committee

PALM People for A Living Moorabool

PCG Project Control Group

SEPP State Environment Protection Policy

SIGNAL Stream Invertebrate Grade Number – Average Level

SKM Sinclair Knight Merz

SRW Southern Rural Water

VEWH Victorian Environmental Water Holder

15 Appendices

Appendix 1 – Fauna species list

Scientific name	Common name	Conservation status (FFG Act / EPBC Act)
Fish		
Gadopsis marmoratus	River Blackfish	Common
Galaxias brevipinnis	Climbing galaxias	Common
Galaxias maculatus	galaxias	Common
Galaxias olidus	Mountain galaxias	Common
Anguilla australis	Short-finned Eel	Common
Galaxias truttaceus	Spotted galaxias	Common
Nannoperca australis	Southern Pygmy Perch	Common
Nannoperca obscura	Yarra Pygmy Perch	Vulnerable (EPBC)
Pseudogobius sp.	Blue-spotted gudgeon	Common
Philypnodon grandiceps	Flat-headed gudgeon	Common
Pseudaphritis urvillii	Tupong	Common
Retropinna semoni	Australian smelt	Common
Mordacia mordax	Shortheaded lamprey	Common
Geotria australis	Pouched lamprey	Common
Prototroctes maraena	Australian grayling	Vulnerable (EPBC)
Macroinvertebrates		
Cheerax destructor	yabby / freshwater shrimp	common
Euastacus spp	spiny cray	Unknown
Engaeus victoriensis (?)	burrowing cray	Endangered
Euastacus spp	Southern Victorian spiny cray	Vulnerable
Mammals		

Ornithorhynchus anatinus	Platypus	common
Hydromyschrysogaster	Water-rat	common
Birds		
Porzanapusilla	Baillon's Crake	Threatened and vulnerable
Grus rubicunda	Brolga	Threatened and vulnerable
Plataleareg ia	Royal Spoonbill	Vulnerable
Egrettagarzetta	Little Egret	Threatened and Endangered
Ardea intermedia	Intermediate Egret	Threatenedand Endangered
Ardea alba	Great Egret	Threatenedand Endangered
Nycticoraxcaledonicus	Nankeen Night Heron	Vulnerable
Anasrhynchotis	Australasian Shoveler	Vulnerable
Aythyaaustralis	Hardhead	Vulnerable
Oxyuraaustralis	Blue-billed duck	Threatened and Endangered
Biziuralobata	Musk Duck	Vulnerable

Data obtained in the Victorian Aquatic Fauna Database, DSE (2005; 2013), FFG Act (1998) and the EPBC Act (1999).

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Appendix 2 – Flora species list (Jacobs 2015)

Zone	Species	Common Name	Saline/groundwater indicator	Conservation Status
FLOWS Reach 1, Moorabool River East Branch: Bostock Reservoir to West Moorabool River				
Aquatic	**Elodea canadensis*	Canadian Pondweed		
	Myriophyllum variifolium	Varied Water-milfoil		
	Ranunculus amphitrichus	Small River Buttercup	x	
	Triglochin procerum (narrow floating leaves)	Common Water-ribbons		
	Periphyton (Abundant)			
Marginal	**Rorippa nasturtium-aquatica*	Water Cress		
	Apium prostratum	Sea Celery	x	
	Carex appressa	Tall Sedge		
	Carex fascicularis	Tassel Sedge		
	Crassula helmsii	Swamp Crassula		
	Eleocharis acuta	Common Spike-sedge		
	Glyceria australis	Austral Sweet Grass		
	Isolepis cernua	Nodding Club-sedge	x	
	Schoenoplectus tabernaemontani	River Club-sedge		
	Typha domingensis	Narrow-leaf Cumbungi		
Damp	**Conium maculatum*	Hemlock		
	**Nasella trichotoma*	Serrated Tussock		
	**Phalaris aquatica*	Toowoomba Canary-grass		
	**Rubus anglocandicans*	Blackberry		
	Acacia dealbata	Silver Wattle		
	Acacia mearnsii	Black Wattle		
	Acacia melanoxylon	Blackwood		
	Acaena novae-zeelandiae	Bidgee Widgee		
	Callistemon sieberi	River Bottlebrush		
	Geranium sp. 2	Variable Crane's-bill		
	Hemarthria uncinata	Mat Grass		
	Hymenanthera dentata var. dentata	Broad-leaf Tree-violet		
	Leptospermum lanigerum	Woolly Tea-tree		
	Poa labillardierei	Common Tussock-grass		
	Pteridium esculentum	Bracken		
	Rumex brownii	Slender Dock		
	Senecio minimus	Shrubby Fireweed		
	Total salt or groundwater indicator species		3	
Reach 3a, Moorabool River: Lal Lal Reservoir to confluence with East Branch				
Aquatic	**Elodea canadensis*	Canadian Pondweed		
	Myriophyllum variifolium	Varied Water-milfoil		
	Triglochin procerum (narrow floating leaves)	Common Water-ribbons		
	Periphyton (Abundant)			
Marginal	*Carex appressa*	Tall Sedge		

Zone	Species	Common Name	Saline/groundwater indicator	Conservation Status
	Carex fascicularis	Tassel Sedge		
	Carex gaudichaudii	Fen Sedge		
	Crassula helmsii	Swamp Crassula		
	Glyceria australis	Austral Sweet Grass		
	Isolepis inunudata	Swamp Club-sedge		
	Persicaria decipiens	Slender Knotweed		
	Phragmites australis	Common Reed		
	Typha domingensis	Narrow-leaf Cumbungi		
Damp	**Conium maculatum*	Tall Sedge		
	**Rosa rubiginosa*	Tassel Sedge		
	**Rubus anglocandicans*	Fen Sedge		
	Acacia dealbata	Swamp Crassula		
	Acacia melanoxylon	Austral Sweet Grass		
	Acaena novae-zeelandiae	Swamp Club-sedge		
	Bursaria spinosa subsp. spinosa	Slender Knotweed		
	Eucalyptus viminalis	Common Reed		
	Gynatrix pulchella s.s.	Narrow-leaf Cumbungi		
	Hymenanthera dentata var. dentata			
	Juncus pauciflorus			
	Leptospermum lanigerum	Hemlock		
	Poa labillardierei	Sweet Briar		
	Pomaderris aspera	Blackberry		
	Pteridium esculentum	Silver Wattle		
	Senecio minimus	Blackwood		
	Total salt or groundwater indicator species		0	
Reach 3b, Moorabool River: Confluence with East Branch to Sharps Road				
Aquatic	**Elodea canadensis*	Canadian Pondweed		
	Myriophyllum variifolium	Varied Water-milfoil		
	Triglochin procerum (narrow floating leaves)	Common Water-ribbons		
	Triglochin procerum (broad erect leaves)	Common Water-ribbons		
	Periphyton- abundant			
Marginal	**Juncus acutus*	Spiny Rush		
	**Juncus articulatus*	Jointed Rush		
	**Salix fragilis*	Crack Willow		
	Carex appressa	Tall Sedge		
	Carex gaudichaudii	Fen Sedge		
	Crassula helmsii	Swamp Crassula		
	Glyceria australis	Austral Sweet Grass		
	Isolepis cernua	Nodding Club-sedge	x	
	Juncus caespiticius	Grassy Rush	x	
	Lobelia anceps	Angled Lobelia		
	Persicaria decipiens	Slender Knotweed		
	Phragmites australis	Common Reed		

Zone	Species	Common Name	Saline/groundwater indicator	Conservation Status
	Schoenoplectus tabernaemontani	River Club-sedge		
	Triglochin striatum	Streaked Arrow-grass	x	
	Typha domingensis	Narrow-leaf Cumbungi		
Damp	**Conium maculatum*	Hemlock		
	**Ulex europaeus*	Gorse		
	Acacia dealbata	Silver Wattle		
	Acacia mearnsii	Black Wattle		
	Acacia melanoxylon	Blackwood		
	Acaena novae-zeelandiae	Bidgee Widgee		
	Bursaria spinosa subsp. spinosa	Sweet Bursaria		
	Coprosma quadrifida	Prickly Currant-bush		
	Dichondra repens	Kidney Weed		
	Eucalyptus camaldulensis	River Red Gum		
	Eucalyptus leucoxylon	Yellow Gum		
	Eucalyptus viminalis	Manna Gum		
	Ficinia nodosa	Knobby Club-sedge	x	
	Gynatrix pulchella s.s.	Hemp Bush		
	Hymenanthera dentata var. dentata	Broad-leaf Tree-violet		
	Leptospermum lanigerum	Woolly Tea-tree		
	Lomandra longifolia subsp. longifolia	Spiny-headed Mat-rush		
	Hymenanthera dentata var. dentata	Broad-leaf Tree-violet		
	Poa labillardierei	Common Tussock-grass		
	Senecio minimus	Shrubby Fireweed		
	Total salt or groundwater indicator species		5	
Reach 4, Moorabool River: Sharps Road to Barwon River				
Aquatic	*Azolla filiculoides*	Pacific Azolla		
	Chara sp	Stonewort		
	Landoltia punctata	Thin Duckweed		
	Lemna tricusularia	Ivy-leaf Duckweed		poorly known
	Triglochin procerum (narrow floating leaves)	Common Water-ribbons		
	Periphyton- locally common in shallow areas			
Marginal	**Cyperus eragrostis*	Drain Flat-sedge		
	**Paspalum distichum*	Water Couch		
	**Polypogon monspeliensis*	Annual Beard-grass		
	Bolboschoenus caldwelii	Sea Club-sedge	x	
	Crassula helmsii	Swamp Crassula		
	Isolepis inunudata	Swamp Club-sedge		
	Lachnagrostis filiformis s.l.	Common Blown-grass		
	Lilaeopsis polyantha	Australian Lilaeopsis	x	
	Mimulus repens	Creeping Monkey-flower	x	
	Persicaria decipiens	Slender Knotweed		

Zone	Species	Common Name	Saline/groundwater indicator	Conservation Status
	Phragmites australis	Common Reed		
	Rumex bidens	Mud Dock		
	Schoenoplectus tabernaemontani	River Club-sedge		
	Triglochin striatum	Streaked Arrow-grass	x	
Damp	*Chenopodium glaucum*	Glaucous Goosefoot	x	
	Duma florulenta	Tangled Lignum		
	Eucalyptus camaldulensis	River Red Gum		
	Hymenanthera dentata var. dentata	Broad-leaf Tree-violet		
	Poa labillardierei	Common Tussock-grass		
	Rorippa laciniata	Jagged Bitter-cress		
	Total salt or groundwater indicator species		5	

* Denotes introduced species

(Moorabool River Flows Study Update, Jacobs 2015)