Tarago and Bunyip Rivers

Environmental Water Management Plan

JUNE 2017









Acknowledgements

Acknowledgement of Country

Melbourne Water proudly acknowledges Aboriginal and Torres Strait Islander people as Australia's first peoples and as the Traditional Owners and custodians of the land and water on which we rely. We pay our respect to their Elders past, present and future.

We recognise and value the strong contribution and interest of Aboriginal people and organisations in waterways and catchment management and how this enriches us. In particular, we acknowledge the Ancestors, Elders and families of the Traditional Owners for the Country through which the Tarago and Bunyip Rivers flows.

We pay respect to the deep traditional knowledge and their custodianship of Country, and acknowledge that the Tarago and Bunyip catchment is a place of age old ceremonies of celebration, initiation and renewal and that this ongoing culture has a unique role in the life of this region.

Contributions

The information contained in the Environmental Water Management Plan has been sourced from a large number of reports, plans and strategies, as well as valuable contributions of knowledge and ideas from many people. We gratefully acknowledge the engagement and contributions of the following stakeholders in preparing this EWMP:

- Western Port Catchment Landcare Network
- Bunyip Landcare
- Drouin Landcare
- Neerim and District Landcare
- Jindivick Landcare
- Irrigators and diverters
- Glen Cromie Caravan Park
- Southern Rural Water
- Gippsland Water
- Port Phillip and Western Port CMA
- Waterwatch (Melbourne Water)
- Environment Protection Authority (EPA)
- Parks Victoria
- Baw Baw Shire Council
- Cardinia Shire Council
- Friends of Robin Hood Reserve
- Native Fish Australia and VRFish
- Department of Environment, Land, Water and Planning
- Melbourne Water
- Victorian Environmental Water Holder
- Western Port Scientific Review Team

Executive Summary

The Tarago and Bunyip Rivers have helped shape Victoria's history and culture, playing a vital role in the lives and livelihoods of people over countless generations. Although flow stressed, both waterways continue to support species and communities of high conservation value, and are important to manage using environmental water.

People have a long and strong connection with the Bunyip River and its major tributary, the Tarago River. This history of connection is thought to extend back for many thousands of years, to the First Nations people and Traditional Custodians, who would have used the rivers' resources, told stories and held ceremonies, and lived along the banks that run from the Dandenong Ranges to the sea at Western Port Bay. To this day, the communities of Westernport highly value the assets of the Tarago/Bunyip system, and are increasingly recognising the importance of protecting them for their health and wellbeing.

This history of connection is marked by major land use changes: from the time before European occupation when Victoria's once largest wetland, Koo Wee Rup Swamp, presented an almost impenetrable barrier in the southern parts of the catchment but provided many resources for people; to now being one of Victoria's major market garden areas and fastest growing municipalities in the State.

Land use change has had major impacts on both rivers, particularly with the drainage of Koo Wee Rup Swamp in the late 19^{th} Century and early 20^{th} Century, and compounded by river regulation and the construction of dams and weirs. It is now further compounded by diversions for irrigation and growing urbanisation. As a consequence, the Tarago and Bunyip Rivers are flow stressed systems, meaning they do not receive enough flows, and that the flows they do receive have a significantly altered flow regime from natural, making it difficult to sustain ecological health.

In recognition of this flow stress, the Tarago and Bunyip Rivers have received an allocation of water specifically for the purpose of improving their ecological health, an Environmental Entitlement, and broader Environmental Water Reserve sources are protected from use for consumptive purposes in the system. This Environmental Water Management Plan sets out the management objectives for environmental water in the system over the next five to ten years, focusing more particularly on the 3000 ML Environmental Entitlement because of its more flexible management. Management objectives for the Environmental Entitlement must be cognisant of broader issues that may affect the Environmental Water Reserve however, so a range of emerging issues are also analysed for their potential impacts and to provide context.

Key values and condition

The Environmental Water Management Plan (EWMP) represents a synthesis of a wide range of reports, studies and strategies, as well as significant stakeholder consultation. The baseline for the discussion and analysis of values and management objectives has been set by Melbourne Water's Healthy Waterways Strategy and re-confirmed through engagement and consultation during the development of the EWMP.

The Healthy Waterways Strategy identifies seven different water-dependent values, and these provide the focus for the EWMP. These are:

- Fish

- Platypus
- Macroinvertebrates
- Frogs
- Vegetation
- Birds
- Amenity.

These values closely align with the community's expectations and aspirations for waterways in the Melbourne Water region, and have been selected because of their importance to the community, the availability of data to assess their condition, and their ability to appropriately represent the range of values found in Melbourne's waterways.

Some of the more specific ecological values in the system include: threatened fish such as the Australian Grayling and Dwarf Galaxias; rare and threatened frogs such as the Growling Grass Frog and Southern Toadlet; and the elusive Warragul Burrowing Crayfish, known to inhabit only a small area along Labertouche Creek (a tributary of the Tarago River). A wide range of vegetation species and communities along the Tarago/Bunyip system are now highly fragmented across the Westernport catchment, and are endangered as a consequence. The iconic platypus also has significant populations in the system, an important and charismatic species for our communities to protect. In addition, many bird species protected under international treaties are found in the southern parts of the system at Western Port Bay, where the Bunyip River estuary directly feeds water to the internationally renowned Ramsar Site.

The Tarago/Bunyip system is also notable for its considerable amenity and liveability values, ranging from good recreation opportunities and interaction with nature along the banks, to community groups and citizen science activities working to protect and improve ecological health.

In acknowledging the importance of reconciliation and collaboration with Traditional Owners, Melbourne Water has included for further work another important asset for the Tarago/Bunyip system; water-dependent cultural values. The Victorian Environmental Water Holder (VEWH) and Melbourne Water have committed to strengthening collaborative management of waterways with Indigenous people in the Melbourne region, an undertaking that is also being applied more broadly across Victoria through State Government commitments in the Water Plan '*Water for Victoria'* (DELWP 2016). Through this EWMP and through separate supporting studies, water-dependent cultural values are now being incorporated for management; although significant engagement and consultation is required with Traditional Owners before specific management objectives for these values can be determined.

The health these values is strongly linked to the flow regime of the Tarago/Bunyip system, including the range of low flows, high flows, freshes and floods experienced by the waterways. Reflecting the flow stress of the system, there have been significant decreases in the abundance and distribution of many native plant and animal species, poor water quality and sedimentation issues impact the freshwater reaches as well as Western Port. River condition is summarised in Table 1.

Table 1 : Condition summary for the values in the Tarago and Bunyip Rivers

Value	Summary of Condition
Fish	Although the diversity of native fish species is relatively good in the upper and lower catchment, the abundance and distribution of many fish species has dropped significantly. For example, Australian Grayling has reduced in extent and abundance to the point it is threatened, and River Blackfish are showing concerning evidence of further declines in their recruitment,

Value	Summary of Condition
	abundance and extent
Platypus	Platypus populations in Westernport are some of the healthiest in the Melbourne Water region, but were badly impacted by the Millennium Drought and are still recovering. Their condition remains very low in both the upper and lower areas of the catchment, which has been further impacted in 2017 by illegal fishing nets causing kill events.
Vegetation	In the upper and less developed areas of the catchment, vegetation condition remains moderate, but is of very low condition in the lower areas of the catchment, reflecting the extensive removal of riparian and floodplain vegetation for land development.
Frogs	Similar to many parts of the world, frog species are significantly reduced in distribution and abundance in the Tarago and Bunyip catchments, with additional impacts of disease such as *Chytridiomycosis* devastating their numbers. However, the upper catchment retains a moderate level of species diversity, while the lower catchment is considered of good condition because of the numbers of species present.
Macroinvertebrates	The condition of macroinvertebrate communities reflects their location within the catchment. The upper catchment has a high rating for condition, due to fewer river regulation impacts and less land use change. The lower catchment is in moderate condition, reflecting this area's purpose as a 'working' river.
Birds	Although very little data is available on streamside, wetland and estuary birds, condition is considered moderate in terms of variety and proportion of native species in the upper catchment, and very low in the lower catchment. When looking at longer-term data for the Western Port Ramsar Site, many species have declined, possibly reflecting diminishing wetland availability, local reductions in fish prey, increasing predation pressure and changes in inland wetland resources.
Amenity	Condition for amenity is difficult to ascertain and measure, but generally poorer areas of access to the waterways reduce amenity values, for example the channelised sections of the system in the lower catchment. Reaches in the upper catchment flowing through natural forest and relatively undeveloped areas reflect higher condition values for amenity.

There are significant knowledge gaps regarding the flow requirements of many of these values, and a number of management actions are provided to help address these gaps.

Threats

Although river regulation and altered hydrology are a major threat to the Tarago and Bunyip River values, there are many other threats that contribute to the general degradation in condition. These include:

- Urbanisation in some parts of the catchment, reducing habitat availability and quality and further altering the flow regime through increased stormwater issues, especially in some tributary streams
- Climate change altering the amount and patterns of streamflow in the catchment
- Runoff from the agricultural areas of lower catchment, increasing nutrient and pollution inputs into the waterway and reducing water quality and habitat availability for instream values
- Barriers to fish movement, reducing upstream and downstream connectivity, as well as to the floodplain and billabongs
- Introduced pests such as deer, foxes, dogs, cats and fish

- Introduced plants, which outcompete native vegetation for habitat space and also reduce habitat quality
- Erosion and sedimentation impacting on habitat availability and quality in the freshwater and estuarine reaches as well as the receiving marine waters of Western Port
- The continuing degradation and loss of riparian vegetation through land use change, including intensification of agricultural activities
- Bushfires reducing water quality and habitat availability as well as altering catchment hydrology
- The continuing drainage management of the former Koo Wee Rup Swamp area for flood mitigation purposes
- Domestic stock access and grazing, which impacts on habitat availability and reduces water quality.

Climate change and land use change are considered significant for the Tarago-bunyip system and have received additional analysis in the EWMP as emerging issues.

Climate change

It is important to remember that the 3000 ML Environmental Entitlement for the Tarago Bunyip system is based on environmental flows studies that recommend ***minimum*** volumes required to achieve ecological objectives for the system, and flows greater than these are preferable if they occur naturally in response to climatic conditions. Furthermore, the Entitlement is constrained in its ability to address all of the flow-dependent ecological objectives for the Tarago/Bunyip Rivers, because the volumes that are needed are greater than what is available under the Entitlement and releases are also limited by a range of delivery, ecological and infrastructure constraints. Full compliance with flow recommendations does not guarantee that the system will cease being flow stressed, and it is likely that as threats associated with climate change are realised, the river's flow stress will get worse.

The implications of climate change for the environmental health of the Tarago/Bunyip system are particularly profound, and it is likely that there will not be enough water under the Environmental Entitlement to maintain the current condition of values, let alone improve them. This is because reductions in water availability, increasing temperatures, and changes in rainfall patterns will all significantly affect the pattern and volume of flows experienced by the system, further decreasing the quality of the water it receives and the quality of the habitat that the system is able to provide. This is likely to cause widespread negative impacts to biodiversity.

A range of priority flow components will need to be delivered with a high degree of compliance to help maintain the current condition of Tarago/Bunyip values. The climate change analysis predicts that in the short term (i.e. the next 10 to 15 years), the condition of key values in the system is likely to remain similar to current, but in the longer term, especially in dry climate years, condition is expected to deteriorate significantly. In order to meet the current management and environmental flow objectives under a climate change outlook (i.e. maintain the current level of achievement with environmental flow recommendations), an increase in the volume of the Environmental Entitlement will be required. It will be important to begin working on this issue within the next 5 years.

Vision and management objectives

The flow-related management objectives for the Tarago/Bunyip system have been developed so that they take into account the current condition and trajectory of values, their threats, and their flow driven life-cycle requirements. Objectives determined by Melbourne Water's Healthy Waterways Strategy provide the primary guidance for these objectives, while the Tarago/Bunyip environmental FLOWS studies and other studies provide the more specific ecological objectives.

Ecological objectives in the EWMP focus on providing flow components that help to maintain a more natural pattern of flow variability: low flows, freshes and high flows. Bankfull and overbank flows are currently not provided through managed environmental water, to reduce the risk of flooding private land, and instead rely on natural events providing these components. The flow components aim to create and/or support ecological functions that are then likely to lead to achieving specific ecological objectives. This is based on the knowledge that particular flow components provide an ecological function (such as providing enough water in a channel for fish movement), which in turn help to support the ecological objectives (such as providing habitat for native fish communities), which in turn support ecological outcomes (such as maintaining the diversity of native fish species in the catchment).

Stakeholder feedback during the development of the EWMP indicated that management objectives need to be tailored to where they apply within the broader catchment. The objectives for the upper catchment, north of Gippsland Rail Line, should reflect that this part of the system retains a more natural hydrology and better habitat for values. Management objectives for the lower catchment, along Bunyip Main Drain, should reflect the functionality of this part of the system for flood mitigation and drainage while still providing connectivity and some habitat for key species. Stakeholders felt it was important to acknowledge the connectivity between the freshwater reaches, the estuary and Western Port Bay.

The Vision Statement is as follows:

Upper catchment

North of the Gippsland Rail Line, the upper reaches of the Bunyip and Tarago Rivers are valued by our community for their high amenity, biodiversity and cultural values and their unique species and we recognise that the long-term condition of these values depends greatly on a secure water source. We will work to protect and where possible restore and enhance the ecological health and function of these reaches, so that they continue to support a rich diversity of self-sustaining indigenous species and the important ecosystem services they provide.

Lower catchment

South of the Gippsland Rail Line, the lower reaches of the Bunyip River and Estuary play an important role in our community, supporting livelihoods and protection from floods. Although highly modified, these parts of the catchment still provide important habitat for endangered species, and we will use our environmental water to protect and improve the quality, connectivity and abundance of their habitat. We will work to cultivate community awareness of the importance of these reaches, in terms of the intrinsic social, cultural, economic and environmental value they provide.

In light of this Vision for the system, the management objectives for provision of environmental flows focus on:

- In the upper catchment: maintaining the full suite of native migratory and non-migratory fish species; and increasing the abundance of native fish. In the lower catchment, maintaining passage for migratory fish moving between the estuary and the upper reaches is important.
- Maintaining high quality vegetation in the upper catchment, and preventing further declines in the lower catchment
- Maintaining the condition of macroinvertebrate communities in the upper and lower catchments
- Maintaining flow conditions suitable for platypus in the lower catchment

- For frogs, birds and amenity, no particular management objectives were provided through the environmental FLOWS study, so general provisions apply for protecting and improving habitat quality and availability.

Risks

Melbourne Water and the VEWH manage the Tarago/Bunyip system's environmental water with diligence and caution, and must continually appraise any risks, being careful to avoid any possible negative impacts while delivering water. This means that environmental flow managers work with Storage Operators in real time to vary delivery to avoid third party impacts while still striving for the best possible environmental outcomes. Risks have been assessed for the environmental watering program using a risk management framework developed by the VEWH.

The risks are categorised as either related to achieving ecological objectives, or risks related to the delivery of the Entitlement water. They include:

- Release volumes being insufficient in meeting required flows at target points
- Current environmental flow recommendations are inaccurate, or there is difficulty in demonstrating outcomes are being achieved through environmental watering, leading to a loss of public/political support
- Environmental releases causing unintended inundation of private land, resulting in impacts on landowner activities and assets
- Further consumptive extraction of water, causing an alteration of natural flow regimes
- Land use change – Such as urban development and the further expansion of irrigation areas
- Sediment inputs to the estuary and Western Port.

Constraints

Due to a lack of infrastructure it is challenging for Melbourne Water to provide environmental water to the upper reaches of the Tarago and Bunyip River. For this reason, Melbourne Water has prioritised releases from the Environmental Entitlement for the reaches downstream of Tarago Reservoir.

Future constraints on Melbourne Water's ability to provide adequate environmental flow volumes include: impacts to the Environmental Water Reserve from drought and climate change; and constraints on the accumulation each year of the Environmental Entitlement volume in storage as result of urban growth. A range of management actions are provided to help address these constraints, including protecting the current Environmental Entitlement releases through strategic arrangements with the Storage Operator and Southern Rural Water, and exploring the feasibility of using alternative water sources to increase and/or augment the Environmental Entitlement when streamflows are low in the Tarago-Bunyip system.

Opportunities

There are good opportunities for Melbourne Water to build on its collaboration and engagement with delivery partners and the community, to achieve 'more and better' outcomes for the environmental watering program. Climate change, while a significant risk, provides a pathway for meaningful dialogue around what people value in the Tarago and Bunyip Rivers, and what is important to protect from a river health perspective as well as a community health and resilience perspective.

Engaging with Traditional Owners to identify and protect water-dependent cultural values presents important opportunities for Melbourne Water and the broader community to move the management of the Tarago-Bunyip system towards a more inclusive, diverse and enriched partnership program. The opportunities for continued capacity building between Melbourne Water, Traditional Owners and the community are very positive, and the intersection of western ecological knowledge and traditional ecological knowledge and connection to Country is likely to strengthen the management of the environmental watering program for better outcomes.

Land use change, and the changing population of the Tarago-Bunyip catchment also present positive opportunities for Melbourne Water, particularly for developing a stronger understanding of amenity and liveability values and how they can best be managed within context. Innovative and integrated approaches to engagement and communications will help to strengthen the relationship Melbourne Water has with the community of the Tarago-Bunyip catchment, and acknowledging that the rivers are seen and valued differently depending on where they are in the catchment will help to achieve this.

Knowledge gaps and demonstrating outcomes

A wide range of short-term, long-term and event-related monitoring actions are undertaken by Melbourne Water to help understand and demonstrate the outcomes of the environmental watering program and to address knowledge gaps. These include ongoing water quality monitoring and compliance monitoring, and more targeted monitoring programs such as tracking the response of Australian Grayling to specific flow releases and eDNA monitoring of platypus populations.

Further research and studies are required for the following:

- **Climate change** – Understanding the impact of climate change on flow regimes, developing a range of flow release scenarios for planning purposes.
- **Estuary** – A dedicated study to assess environmental flow requirements for the Bunyip estuary using the Estuary Environmental Flows Assessment Method for Victoria (EEFAM) would help improve the understanding of the flow requirements in the estuary and more generally in Western Port.
- **Platypus** - The current understanding of the flow requirements of platypus in the Tarago and Bunyip River system needs improvement. It will be particularly important to improve understanding of the existing platypus population, including its resilience and appropriate condition/response assumptions for different water availability scenarios under climate change.
- **Waterbirds and frogs** - Very little is known of the environmental flow requirements of waterbirds and frogs in the Tarago and Bunyip catchments.
- **Amenity** - Given the increasing priority that people place on amenity values, it will be important to be able to link these values with flow requirements where they are known.
- **Water-dependent cultural values** - Currently there is very little knowledge available for waterway managers to help ensure that water-dependent cultural values are protected and managed appropriately and sensitively in Australia.
- **Groundwater** - Targeted hydrogeological assessments, particularly if coordinated with hydrological and ecological survey and monitoring, will improve the understanding of the role of groundwater in the Tarago and Bunyip catchments.

Next steps

This EWMP provides the overarching strategy for the management of environmental water and protection of water-dependent values in the Tarago/Bunyip system for the next five to ten years. It provides the basis of annual planning for the management of the Environmental Entitlement, most notably providing the direction for future Seasonal Watering Proposals and the development of Melbourne Water's environmental water annual work program.

Figure 1 shows the contribution of EWMP information towards the annual seasonal planning processes for both Melbourne Water and VEWH. The numbers in brackets in the Tarago/Bunyip EWMP box correspond to the numbered topics in the Seasonal Watering Proposal box.

Figure 2 provides a summary of issues and management actions for the Tarago-Bunyip EWMP.

Management actions are summarised in Table 2.

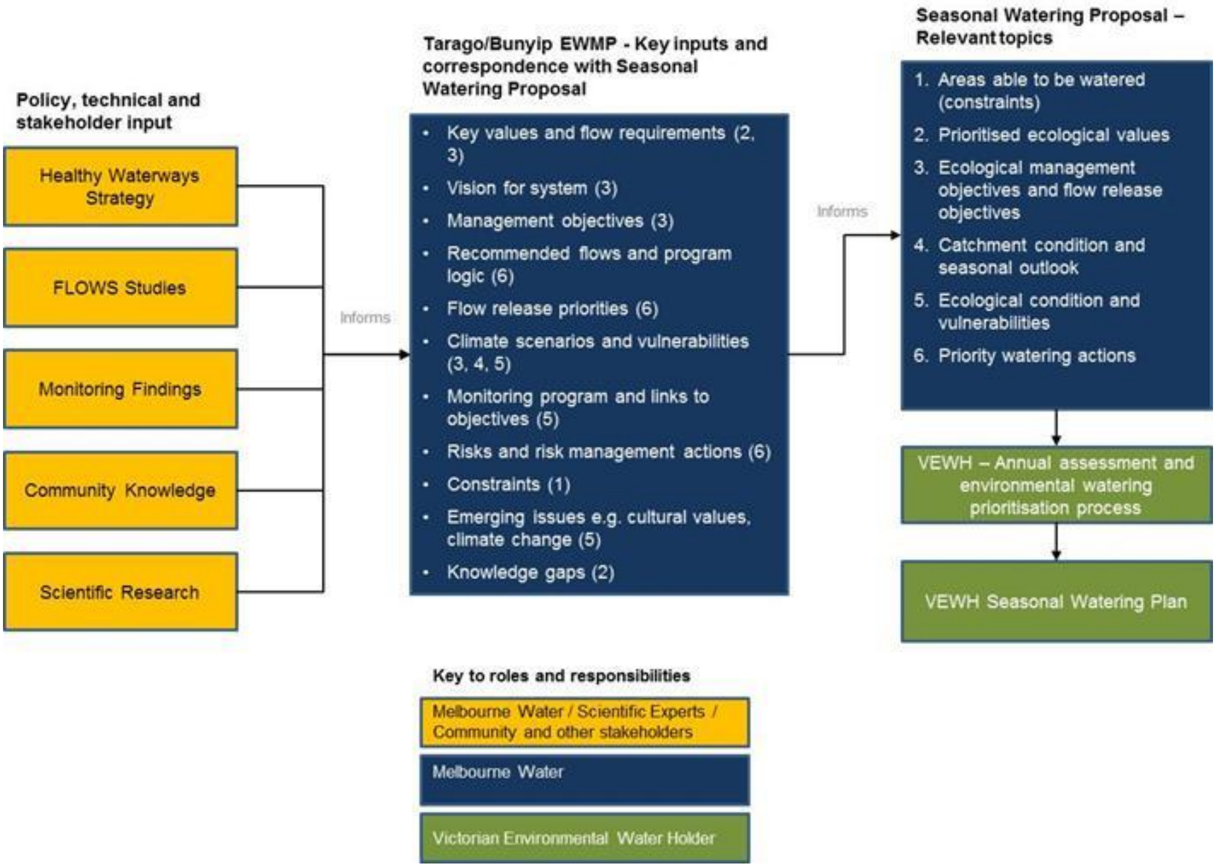

Figure 1 : The contribution of EWMP information to Seasonal Watering Proposal content

Figure 2 : Summary of Tarago-Bunyip environmental water issues and management focus

Summary of Management Actions

Management actions found within the EWMP's body of text have been summarised in Table 2. Management actions associated with specific threats and risks are provided in the appendices.

Table 2 : Management actions

Value/issue	Threat	Implication	Actions
Management actions relating to specific values			
Fish	• River Blackfish numbers are declining, with evidence of poor recruitment. • Climate change could exacerbate threats.	• Loss/extinction of the species from the catchment	• Melbourne Water will conduct further research to better understand the influence of flow on River Blackfish and update seasonal planning as necessary • Complementary actions to protect and improve habitat availability and quality
	• Gaps in knowledge still exist regarding Australian Grayling ecology and links with flow	• Inadequate flow regime to maintain resilience of the species • Consequent reduction in abundance and distribution or possible local extinctions	• Melbourne Water will conduct further research to better understand the influence of flow on immigration and upstream dispersal • Melbourne Water will implement the Australian Grayling recommendations from ARI (2017)
Platypus	• New knowledge not incorporated into platypus management strategy	• Drowning of platypus babies • Poorer habitat quality and availability • Reductions in population distribution and abundance	• Melbourne Water will incorporate new platypus knowledge in to the environmental watering program for the Tarago/Bunyip system and adjust flow provisions where identified • Platypus knowledge will be further reviewed and incorporated into the next review of the environmental FLOWS study
Birds	• Gaps in understanding of relationship between hydrological regime and riparian habitat for Helmeted Honeyeaters	• Inadequate or inappropriate provision of flows, impacting on the condition of this value	• Melbourne Water to support/participate in further research into hydrology impacts on Helmeted Honeyeater habitat
	• Gaps in understanding regarding the flow requirements of	• Inadequate or inappropriate provision of flows, impacting on the	• Melbourne Water will incorporate new knowledge in to the environmental watering

Value/issue	Threat	Implication	Actions
	streamside birds in the catchment	condition of this value	program and adjust flow provisions as it is identified
Frogs	• Frogs are not currently provided with flow recommendations in the catchment	• Inadequate or inappropriate provision of flows, impacting on the condition of this value	• Melbourne Water will continue to consult with researchers to increase knowledge and understanding of frog flow requirements and incorporate into the environmental watering program on an ongoing basis
Macroinvertebrates	• Climate change and land use change may impact water availability and habitat for Warragul Burrowing Crayfish species, by reducing water table and/or wetted sub-surface habitat	• Possible loss of habitat extent and/or quality for threatened species such as Warragul Burrowing Crayfish through inadequate flows provision	• Melbourne Water will undertake research to better understand dependence of the Warragul Burrowing Crayfish on surface water and groundwater flows • Work to understand the connectivity and protection of groundwater/surface water in Labertouche Creek
Amenity and Community	• The flow requirements of amenity values are poorly understood and difficult to measure in terms of condition changes	• Inadequate or inappropriate provision of flows, impacting on the condition of these values for communities	• Melbourne Water is working to improve the sub-measures for amenity • Where possible, flow provisions for amenity values will be incorporated for management over time
	• Poor and/or decreasing community engagement and understanding of waterway values	• May decrease the 'social licence' of Melbourne Water and VEWH to provide environmental flows, particularly during times of drought and/or climate change impacts	• Melbourne Water will continue to deliver and support community engagement, education and awareness raising activities • Melbourne Water will explore the feasibility of delivering a range of innovative social media and citizen science programs focused on the Tarago-Bunyip system to facilitate this engagement
Water-dependent cultural values	• The flow requirements of water-dependent cultural values are poorly understood and not yet well integrated into water management programs	• Inadequate or inappropriate provision of flows could impact on the condition and continuity of these values • Impacts on Aboriginal community health	• There are good opportunities for Melbourne Water to work with Traditional Owner groups to identify and document water-dependent values and their flow requirements and incorporate into the environmental watering program on an ongoing

Value/issue	Threat	Implication	Actions
		and wellbeing	basis • Melbourne Water will also document and incorporate water-dependent values into its broader waterways management strategies where culturally appropriate, such as the Healthy Waterways Strategy
Estuary flow requirements	Estuary flow requirements are not well defined for the Bunyip River	Inadequate and/or inappropriate flow regimes are provided to the estuary, impacting on the condition and abundance of estuarine dependent species and communities as well as Western Port Ramsar site species and communities	• Melbourne Water will undertake a dedicated study to assess environmental flow requirements for the Bunyip estuary using the Estuary Environmental Flows Assessment Method for Victoria (EEFAM). • This will help to improve the understanding of the flow requirements in the estuary and more generally in Western Port.
Management actions relating to threats			
Urban development and population growth	• Increasing DCI and associated stormwater impacts in the mid reaches • Increasing urban water demands and extraction from Pederson Weir	• Poor habitat quality and direct impacts on species and communities will impact on Melbourne Water's ability to protect and/or improve condition of water-dependent values • Accumulation of the Environmental Entitlement volume may be considerably slowed down, impeding the ability to provide appropriate flow volumes	• Melbourne Water will continue to work with key delivery partners to develop and deliver appropriate stormwater management strategies that help to protect flow regimes. • Melbourne Water will work with key delivery partners to understand the likelihood and consequences of increasing demands for extraction at Pederson weir. • Melbourne Water will work with key delivery partners to explore the feasibility and risks of using alternative water to augment the Environmental Entitlement
Management of Koo Wee Rup area for flood mitigation	• Ongoing erosion and sedimentation issues	• Poor water quality and consequent impacts to habitat within Bunyip River and the receiving waters of Western Port	• Melbourne Water will continue to consult and work with key delivery partners to improve understanding of the link between ongoing drainage of Koo Wee Rup area and sedimentation impacts in

Value/issue	Threat	Implication	Actions
			Western Port.
Opera House Nets	• Illegal use of opera house nets in public waters in Victoria, and Melbourne Water has had drastic impacts on platypus	• Local extinction of platypus	• Melbourne Water will engage and communicate with communities to ensure greater awareness of the consequences of using these nets.
Deer	• Direct impacts on vegetation, catchments and species/communitie s	• Poor quality and availability of habitat for native species and communities, decreasing their population abundance and distribution	• While this threat cannot be managed or mitigated by environmental flows, Melbourne Water will work with key delivery partners to increase understanding of the extent of the problem and possible management actions.
Groundwater / surface water interactions	• Bushfire and timber harvesting in the upper catchment changing the rates and pattern of groundwater recharge • Urbanisation and land use change decreasing recharge in the mid catchment, reducing baseflows in reaches further downstream	• Loss of habitat for GDEs	• Melbourne Water will continue to work with key delivery partners to increase knowledge and understanding of the likelihood, risks and consequences of this threat.
Protecting environmental flow releases	Environmental flow releases are diverted out of the waterway by irrigators	Poor compliance with environmental flow recommendations and subsequent impacts on ability to achieve ecological objectives	• Melbourne Water will consult with Southern Rural Water (SRW) to better understand the impacts and risks of diversions occurring during releases. • Melbourne Water will also complete a project in 2017/18 examining the relationship between flow compliance and ecological outcomes, to better understand the consequences of poor flow compliance under a variety of flow scenarios.
Protecting environmental flow releases	• Environmental flow releases are diverted out of the waterway by irrigators	• Poor compliance with environmental flow recommendations and subsequent impacts on ability to achieve ecological	• Melbourne Water will consult with Southern Rural Water (SRW) to better understand the impacts and risks of diversions occurring during releases.

Value/issue	Threat	Implication	Actions
		objectives	• Melbourne Water will also complete a project in 2017/18 examining the relationship between flow compliance and ecological outcomes.
Climate change	• Inadequate preparation for the impacts of climate change on streamflow and a compromised ability to comply with environmental flow requirements	• Loss of condition for species and communities, local extinctions, decreases in abundance and distribution, poor resilience of water-dependent communities.	• Over the next 5 years, Melbourne Water will work towards improving understanding and planning for the impacts of climate change on streamflows in the catchment. • Melbourne Water will incorporate climate change knowledge into seasonal planning and projected demands, especially shortfalls. • Melbourne Water will also prepare a business case for improving on shortfalls, including exploring options to increase and/or augment the Environmental Entitlement.
Decommissioning of BMR and TMR	• Possible loss of environmental water to Cannibal Creek	• Loss of habitat and poorer habitat quality for key threatened species such as Dwarf Galaxias	• The findings and recommendations of a Cannibal Creek flows review will be incorporated by Melbourne Water into future FLOWS study reviews. • Melbourne Water will also use this knowledge to explore a range of options for maintaining flows to Cannibal Creek if required.
Floodplain connectivity	• Bankfull and overbank flows are not provided	• Loss of habitat and poor habitat for species/communities dependent on floodplain areas. • Consequent reduction in their abundance and distribution. • Possible local extinctions	• Over the next 5 to 10 years, Melbourne Water will explore the feasibility of delivering targeted and strategic overbank flows to areas of the system where flood risks and/or impacts can be mitigated and minimised.

Chapter 1 – Catchment Overview

Winding their way through Westernport catchment in the Greater Melbourne region, the Tarago and Bunyip Rivers have shaped Victoria's history and culture, playing a vital role in the lives and livelihoods of many people over thousands of years. Although their hydrology has considerably changed because of river regulation, to the point their ecological condition reflects flow stress, both waterways continue to support high value species and communities and are important to manage using environmental water.

1 Introduction

This Environmental Water Management Plan (EWMP) outlines Melbourne Water's objectives and priorities for the use of environmental water in the Tarago and Bunyip system. The EWMP informs the development of Melbourne Water's Seasonal Watering Proposals, which are required to be produced under section 192A of the Victorian *Water Act 1989*.

1.1 What are Environmental Water Management Plans?

Environmental Water Management Plans (EWMPs) are evidence-based plans for waterways that describe their water-dependent environmental values, the risks and threats faced by these values, and how these values should be managed in terms of objectives and ecological outcomes. Extending over a five to ten year lifespan, EWMPs are developed for flow stressed waterways, where river regulation and the extraction of water for consumptive purposes means not enough water remains in these systems to sustain their ecological health.

EWMPs focus on flow stressed waterways, floodplains and/or wetlands that can be targeted for management through environmental water management interventions. The scope of an individual EWMP generally includes those reaches, wetlands and/or floodplains where environmental flows can be actively managed, while still remaining as a single Environmental Water Management Unit (EWMU). 'Actively managed' in this case means where an Environmental Water Manager can flexibly manage or modify the volume and/or patterns of flow being provided to a waterway, usually on a yearly or seasonal basis. This environmental water is sourced from an environmental entitlement, from provisions in bulk entitlements, or from other management arrangements such as Stream Flow Management Plans.

In the case of the Tarago and Bunyip Rivers, water is provided for environmental purposes through the *Tarago and Bunyip Rivers Environment Entitlement (2009)*, via rules for minimum flows in a number of bulk entitlements, and also from the protection of above cap water as part of the Environmental Water Reserve.

The program to manage the delivery of environmental water from the Environmental Entitlement is under the joint responsibility of Melbourne Water in its role as a caretaker of river health and day-to-day manager of flow releases in the Tarago/Bunyip system, and the Victorian Environmental Water Holder (VEWH) through its role as the independent statutory body responsible for making decisions on the most efficient and effective use of Victoria's environmental water entitlements. Both agencies have the ability to collaboratively address a range of waterway health needs along the Tarago/Bunyip system by actively providing and then managing environmental flows.

This EWMP plays an important role in maintaining and enhancing the values of the Tarago/Bunyip system by describing how the Environmental Entitlement will be effectively managed to help address flow stress issues and ensure that the health and functioning of water-dependent flora and fauna is maintained or improved.

1.2 What is included in the scope of the EWMP?

The environmental flow requirements of the Tarago/Bunyip system were assessed via an environmental FLOWS study in 2006 (EarthTech 2006a, c, b), and reviewed in 2013 (SKM 2013). The main channels for both the Bunyip and Tarago Rivers were included in the assessments, as well as two tributaries, Labertouche Creek and Cannibal Creek, because of the significant environmental values these smaller waterways support.

The main reaches that can be actively provided with water from the Environmental Entitlement include:

- The Tarago River downstream of the Tarago Reservoir
- The Bunyip River from its confluence with the Tarago River
- The Bunyip Estuary (part of the Bunyip Main Drain), from Koo Wee Rup township to the mouth of the river into Westernport Bay (Figure 3).

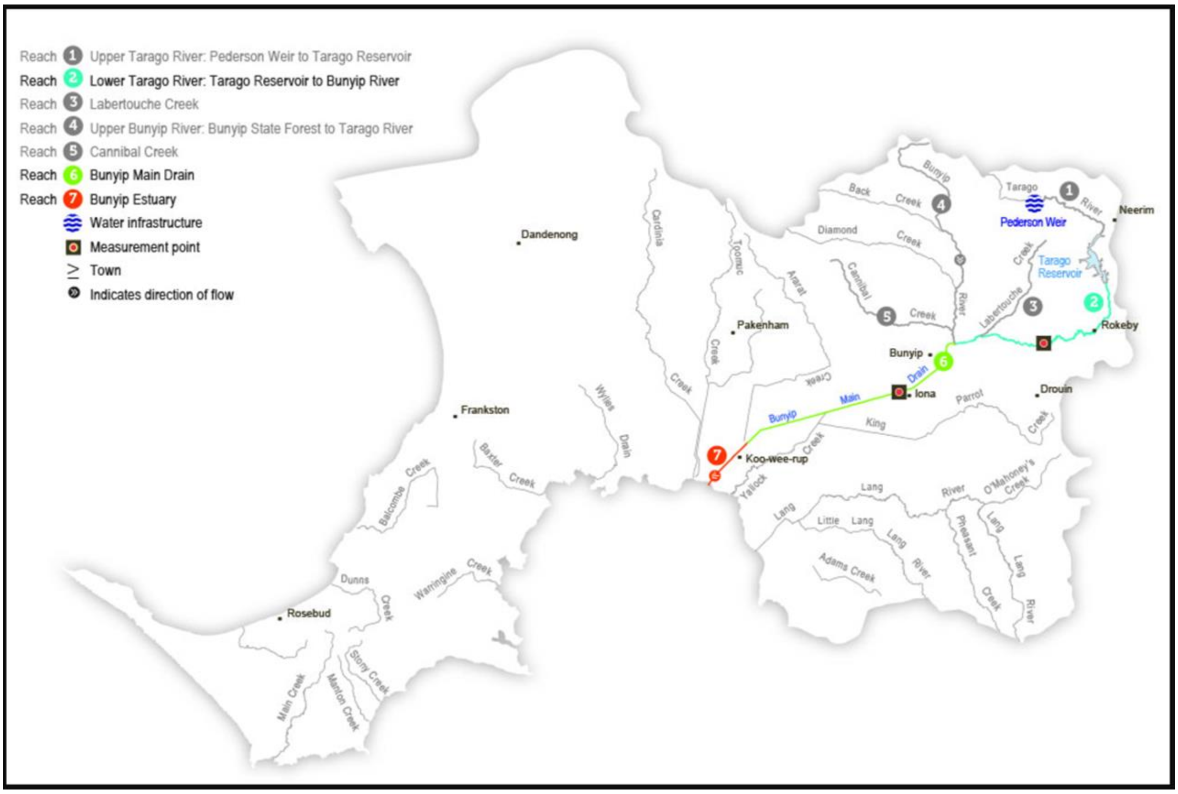

Figure 3 : Tarago and Bunyip reaches for environmental water management. Reaches 2, 6 and 7 can receive environmental water (Source: VEWH (2016))

The primary focus for Melbourne Water and VEWH is on providing flows to those reaches that can be actively and flexibly watered using the Environmental Entitlement water; Reach 2, Reach 6 and Reach 7. If opportunities arise over the next five to ten years to provide additional water to the upper reaches of the Tarago and Bunyip, as well as to Cannibal Creek and Labertouche Creek, these will then be more actively managed and included as priority reaches for watering.

The flows studies for the Tarago/Bunyip system have considered the following flow components: Winter/Spring and Summer/Autumn low flows, freshes and high flows; and Winter/Spring bankfull flows and overbank flows, where:

- Low flows generally provide a continuous flow through the channel. This may either maintain the flow above a 'cease to flow', or provide habitat as a change from 'high flows'
- Freshes are small or short duration peak flow events. These flows exceed the base flow and last for at least several days. Freshes are a key contributor to the variability of flow regimes, providing short pulses in flow, increasing access to habitat and freshening water quality.
- High flows are persistent increases in the seasonal base flows that remain within the channel. They do not fill the channel to 'bankfull'. High flows help water vegetation on the banks, trigger fish spawning and flush accumulated sediment from riffles, hence improving habitat quality for macroinvertebrates.
- Bankfull flows are flows of sufficient size to reach the top of the river bank with little flow spilling onto the floodplain. Bankfull flows are important for maintaining natural rates of erosion and sedimentation, which collectively help maintain the physical structure (geomorphology) of the river channel.
- Overbank flows are flows that result in inundation of adjacent floodplain habitats. These flows are critical for a range of ecological factors, including floodplain productivity and wetland inundation (Figure 4).

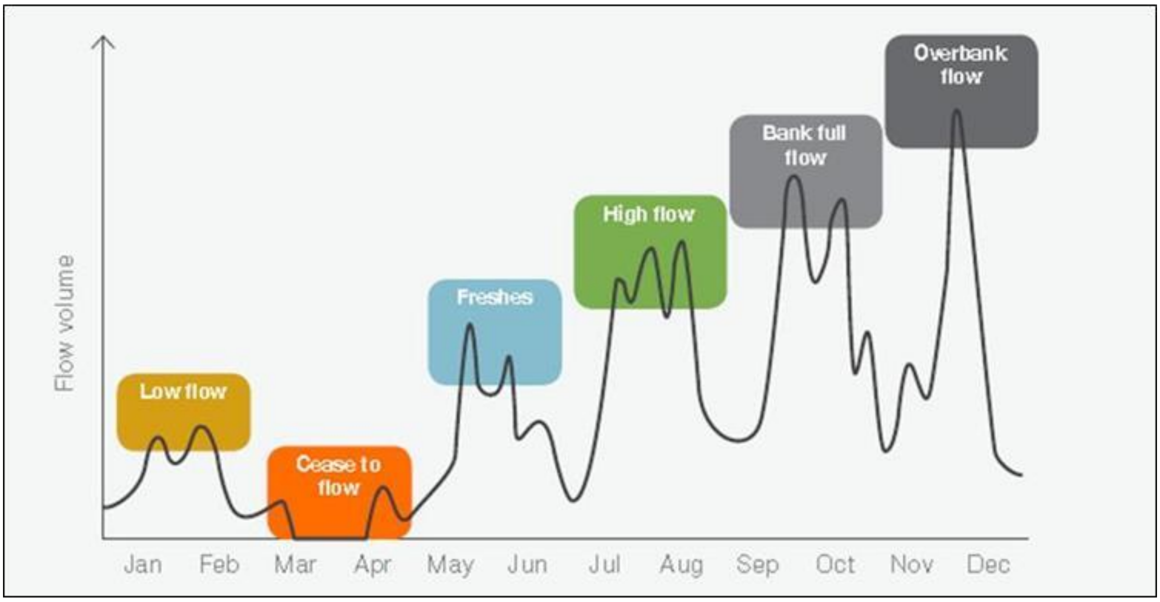

Figure 4 : Typical natural flow pattern of a Victorian river before construction of dams, weirs and channels (Source: (VEWH 2016)

1.3 Why is it important to provide environmental water?

Once providing water to what was Victoria's largest wetland, Koo Wee Rup Swamp, the Bunyip River and its tributaries have been regulated, reshaped and harnessed to provide land and flood protection for communities who live and make their livelihoods in the catchment, draining the wetland completely in the process. For many thousands of years, the Country of the Tarago and Bunyip Rivers would have supported Wurundjeri, Bunurong and Gunai Kurnai people for all aspects of their existence including fishing, hunting and gathering, agriculture and trade, as well as cultural and spiritual gatherings. The contemporary and non-Aboriginal uses of the catchment have changed the system so much that it is unlikely it would be recognisable to pre-European contact Aboriginal people.

Figure 5 shows a timeline of land use for the catchment, and illustrates the continuing land use changes faced by the catchment and more specifically the waterways.

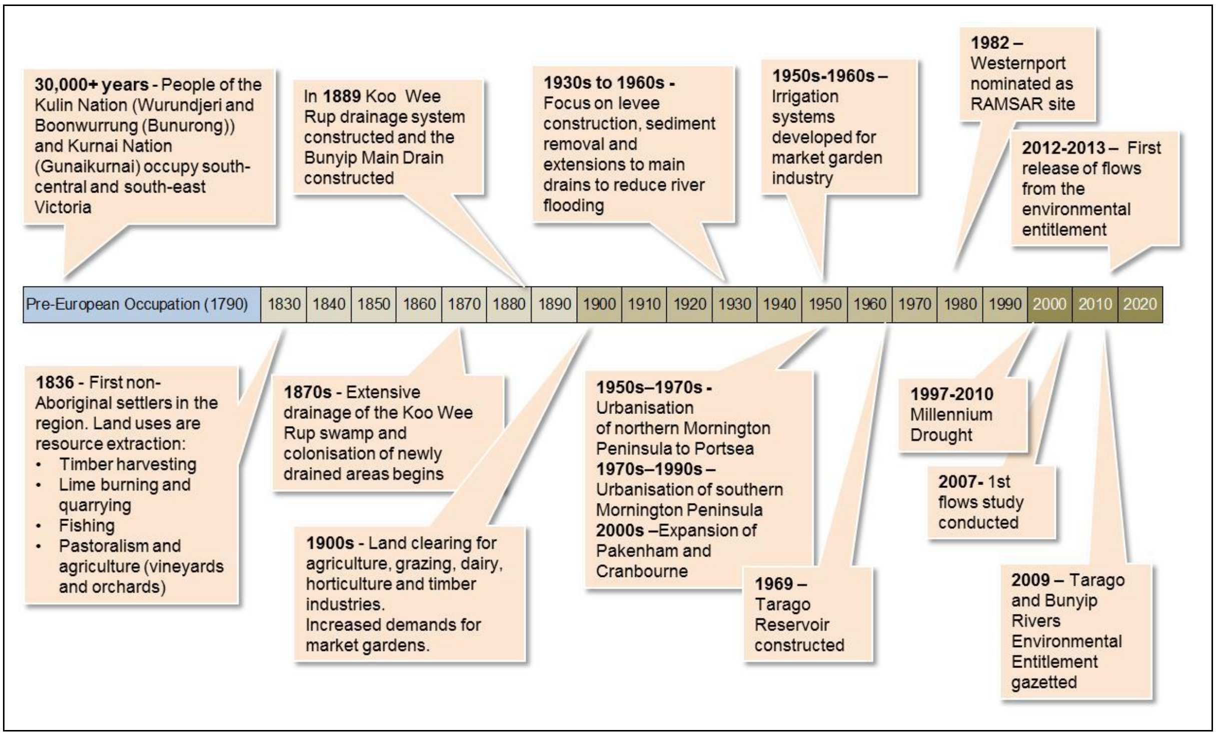

Figure 5 Timeline of land use in the Tarago and Bunyip catchments (Source: Adapted from (Melbourne Water 2013)

The construction of dams and weirs, diversions and extraction of water, and the restructuring of the waterways for flood management and drainage have all contributed towards the flow stress of the Tarago and Bunyip Rivers. Despite the major changes to hydrology, and the significant impacts on ecological health and functioning, the Tarago and Bunyip system remains a highly valued waterway for the community because of the significant plant and animal communities it still supports, for the strong economic productivity it provides, and for its social values, such as amenity and liveability, which play intrinsic and tangible roles in community health and wellbeing.

The Tarago and Bunyip catchments present somewhat of a dual nature for management, determined predominantly by land use and geology, and geographically bisected by the Gippsland Rail Line. The highly modified reaches of Bunyip Main Drain in the lower catchment found to the south of the rail line contrast with the more natural reaches in the upper Tarago and Bunyip to the north of the rail line, and the EWMP has been structured to reflect this difference. In recognition of the hills to sea journey of streamflows in the Tarago/Bunyip system, the EWMP also recognises the connectivity of flow to Western Port and the high conservation value Ramsar site located there.

2 Catchment setting

The Bunyip River is located about 95 km east of Melbourne and is the largest waterway in the Westernport catchment. With a total catchment area of 979 km^2, it rises in the Bunyip State Forest in the basin's north-west and flows south to Longwarry North, where it is joined by the Tarago River. The river continues south-west to the township of Bunyip, where it then changes to a straightened channel that flows through the township of Koo Wee Rup and discharges into the northern section of Western Port Bay.

The Tarago River is a major tributary of the Bunyip River, rising in the north east of the catchment, where it flows through the Tarago State Forest. Tarago Reservoir, constructed in 1967, is situated near the township of Neerim South. Downstream of the

Reservoir, the Tarago River flows south west where it meets with the Bunyip River (Figure 6).

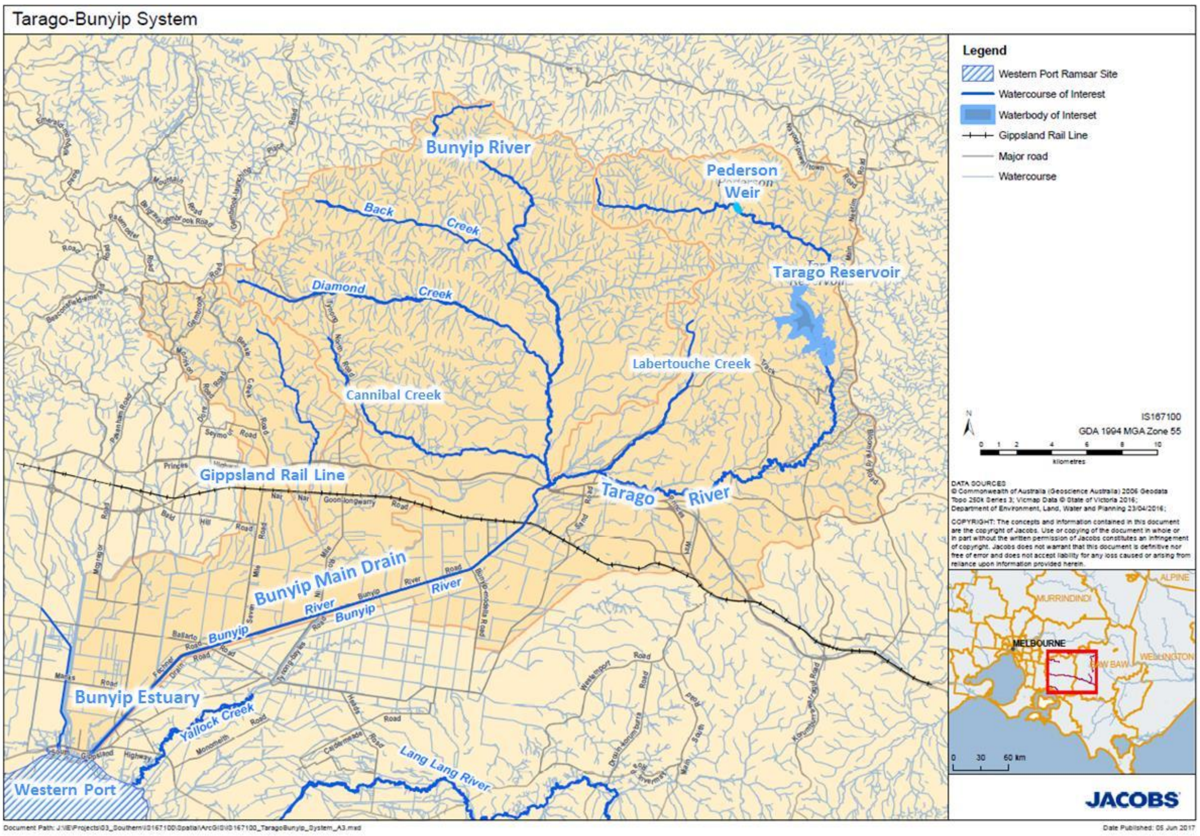

Figure 6 : Tarago and Bunyip Rivers system

Based on consultation undertaken during the development of the EWMP, the system has been divided into two catchment areas: the less developed upper catchment to the north of the Gippsland Rail Line; and the more developed lower catchment to the south. The location of Gippsland Rail Line is shown on Figure 6.

Towns in the catchment area include Koo Wee Rup, Garfield, Bunyip, Drouin, Tarago, Jindivick, Tonimbuk, Neerim South and Longwarry.

Rainfall varies from 750mm to 850mm in the lower lying areas of the catchment, up to 2100mm per year in the forested upper catchment.

With good rainfall and fertile soils, the region produces livestock, vegetables, cut flowers and orchard fruits. Of particular note is the region's vegetable output, with almost 90 per cent of Victoria's asparagus produced in and around Koo Wee Rup, and celery (50%) and leeks (71%) also accounting for significant proportions of the state's output. These agricultural values are significant. The Bunyip River is located in the Westernport Green Wedge Zone[1], where agriculture employs approximately 2,000 people and contributes an estimated $400 million to the local economy, making it the most valuable and productive Green Wedge Zone in Melbourne (Cardinia Shire Council and Alluvium 2015).

[1] The non-urban areas of metropolitan Melbourne that lie outside the Urban Growth Boundary are known as green wedges. There are 12 designated green wedge areas across 17 municipalities which form a ring around the city.

2.1 Important Catchment Values

A number of assets with very high conservation values are found in the region, including the Western Port Ramsar Site. The region also supports important remnant habitats for three different bioregions.

An important value that once existed in the catchment, but which has now largely been drained and removed, is Koo Wee Rup Swamp. This plays an important role in the current functioning of the system.

2.1.1 Western Port Ramsar Site

The Bunyip River is directly connected to the Western Port Ramsar site (Figure 7). Declared in 1982, a large portion of Western Port Bay is designated as a wetland of international importance under the *Convention on Wetlands of International Importance* (KBR 2010).

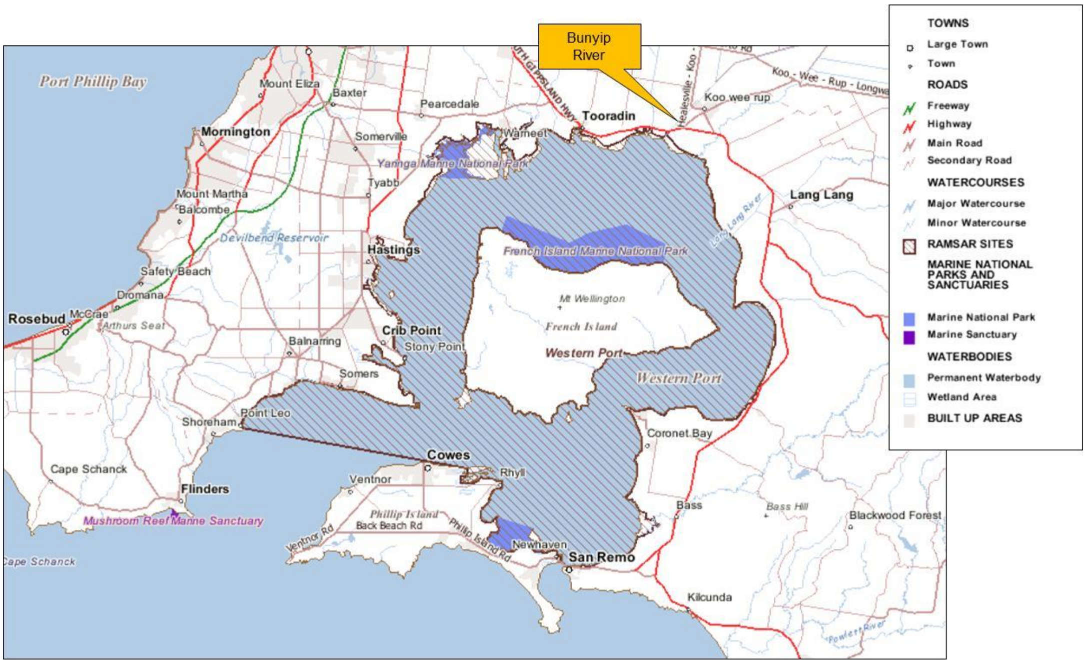

Figure 7: Western Port Ramsar Site (shaded area) (Source: Adapted from DELWP (2017))

The Ramsar Site is superficially similar to Port Phillip Bay to the West, but its geomorphology and its broad range of physical processes provide a wide variety of different habitat types within a relatively confined area, making it a more complex ecosystem. The habitats in the Ramsar Site range from reefs typical of the open coasts in the south-west of the bay, to sheltered mangroves and mudflats in the north. A large tidal range, particularly in the north of the bay, produces extensive intertidal habitats (Keough *et al.* 2011). At low tide, approximately 40% of Western Port is exposed mudflats. These mudflats support seagrass communities and macro-algae, molluscs and crustaceans, and abundant small fish, all of which provide important food sources for birds, mammals and larger fish.

Seagrasses

Seagrasses are highly specialised flowering plants that can live entirely immersed in seawater. They play an important role as 'ecosystem engineers' in Western Port, trapping and stabilising sediments, absorbing nutrients, and acting as a buffer between the catchment and marine habitats (Walker 2011). They also provide habitat for a wide diversity of animals, supporting many fish of conservation, commercial and recreational importance in Western Port (Walker 2011).

Between the mid-1970s and 1984 seagrass cover in Western Port fell dramatically, from 250 km^2 (covering approximately 37% of the Bay) down to 72 km^2 (Walker 2011). The greatest losses were in the intertidal banks of the north-eastern sections of Western Port and where the Bunyip and Lang Lang Rivers enter. Increased suspended sediment loads and increased levels of nutrients in Western Port are thought to have been the major causes of this dieback, with both of these threats generally thought to be a prevalent mechanism in seagrass decline worldwide[2] (Duarte *et al.* 2008, Walker 2011).

Fish

A number of fish species in Western Port are of conservation concern and have been listed under various Acts or placed on internationally recognised lists of threatened species. These include:

- Pipefish and seahorses (*Syngnathidae*) (*EPBC Act 1999*[3], *CITES*[4], *IUCN Red List*[5] *(some species), Fisheries Act 1995*)
- Pale Mangrove Goby (*Mugilogobius platynotus*), Victoria's only estuarine species listed under the *FFG Act 1988*[6]
- Australian Grayling (*Prototroctes maraena*) (*EPBC Act 1999; IUCN Red List; FFG Act 1988*)
- School Shark (*Galeorhinus australis*) (*EPBC 'conservation dependent', IUCN Red List*)
- Great White Shark (*Carcharodon carcharias*) (*EPBC Act 1999; IUCN Red List; FFG Act; Fisheries Act 1995*) (Jenkins 2011).

Western Port is a key breeding area for Elephant Fish (*Callorhinchus milii*), School Shark and Australian Anchovy (*Engraulis australis)*, and is a known nursery area for important fishing species such as King George Whiting (*Sillaginodes punctatus*), Yellow-eye Mullet (*Aldrichetta forsteri*) and Australian salmon (*Arripis spp.)* (Jenkins 2011, Melbourne Water 2011).

Birds

The 27,000 ha of intertidal mudflat in Western Port is a very important habitat for migratory and resident shorebirds, and is ranked third among shorebird sites in Victoria and among the top 20 in Australia for numbers (Dann 2011). The Ramsar Site supports over 30 species that are migratory and listed under bilateral agreements, initiatives and conventions for the conservation of migratory birds. Twenty-nine species are listed under the Japan–Australia Migratory Birds Agreement and 31 species are listed under the China–Australia Migratory Birds Agreement, regularly being found in the Western Port Ramsar site (Dann 2011).

2.1.2 Tidal regime, hydrodynamics and catchment inflows

Although not a large volume in comparison with the seawater influx, it is estimated that as much as 75% of the total freshwater inflows to Western Port Bay come from the Bunyip River, Lang Lang River and Cardinia Creek systems (Shapiro 1975, Longmore 1997). Water from the Bunyip River directly enters Western Port in the northern arm of the Bay, with its freshwater inputs generally travelling in a clockwise direction around the Bay until exiting the system into Bass Strait.

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[2] High nutrient levels are thought to cause excess epiphyte, macroalgal and phytoplankton growth in the water column, which shades seagrass leaves and negatively affects their health (Duarte *et al.* 2008). Suspended sediments smother leaves and reduce light penetration within water, again affecting the health of the plants by reducing their photosynthesis capabilities.

[3] Commonwealth Environment Protection and Biodiversity Conservation Act 1999 (EPBC Act)

[4] Convention on International Trade in Endangered Species of Wild Fauna and Flora

[5] International Union for Conservation of Nature (IUCN)

[6] Victorian Flora and Fauna Guarantee Act (1988)

Associated with this freshwater influx to the Bay is sediment. The major inputs of sediment to Western Port can be split into three main sources: in-stream bank erosion; catchment erosion; and coastal erosion of the shoreline, with channel and gully erosion of the Bunyip and Lang Lang River systems providing the dominant sources of the fine sediment to Western Port (Wallbrink and Hancock 2003, KBR 2010, Lee 2011). The vast majority of the catchment derived sediment inputs come from the agricultural lands in the lower catchment (85%) (Hughes *et al.* 2003). The dominant source for fine sediment is channel and gully erosion of Lang Lang River and, to a lesser extent the Bunyip River (Wallbrink and Hancock 2003). This issue is discussed further in Section 4.2.

2.1.3 Bioregions

The Tarago and Bunyip Rivers are found within the South East Coastal Plain Bioregion of Australia, and three sub-bioregions are found in their catchments: Gippsland Plain; Highlands Southern Fall; and the Strzelecki Ranges (Figure 8).

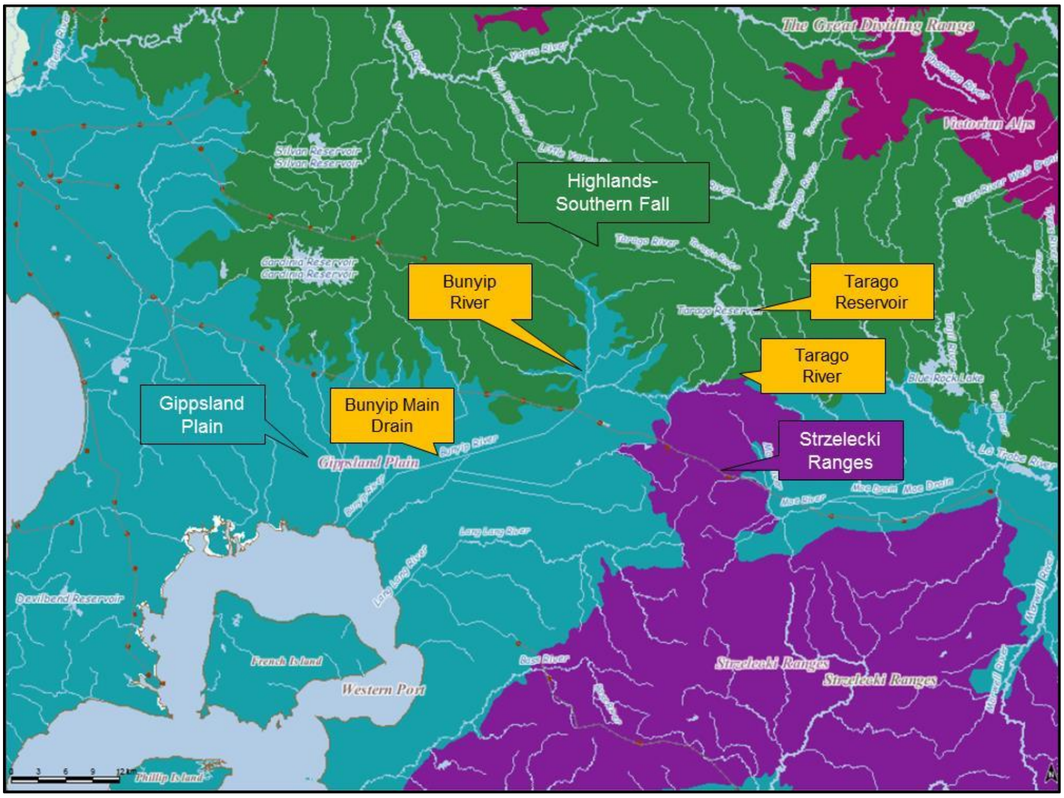

Figure 8 : Sub-bioregions of the Tarago and Bunyip River catchments (Source: Adapted from DELWP (2017))

A significant number of the Ecological Vegetation Classes (EVCs) associated with these bioregions are considered depleted, vulnerable or endangered (DSE 2017). The bioregional vegetation is discussed further in Section 3.3.

2.1.4 Koo Wee Rup Swamp

In the lower Bunyip catchment, the land once supported a large wetland called Koo Wee Rup Swamp, occupying approximately 40,000 hectares (Figure 9). With European settlement of the area, the swamp began being drained in the 1850s, predominantly for flood protection and agricultural purposes. The wetland was covered by dense stands of Swamp Paperbark (*Melaleuca ericifolia*) around the edges, open water, and reeds (*Phragmites australis*) and bullrushes (*Typha spp*) in the inner swamp area. The Swamp provided a natural barrier between Melbourne and West Gippsland and was once Victoria's largest wetland.

As a result of changing land use, many of the waterways in the lower catchment have been modified to become drains. Prior to these changes, the Bunyip River did not reach Western Port, instead fanning out and providing water to maintain the wetland permanently. Remnants of vegetation and animals communities remain in the area, supporting a number of rare and threatened species.

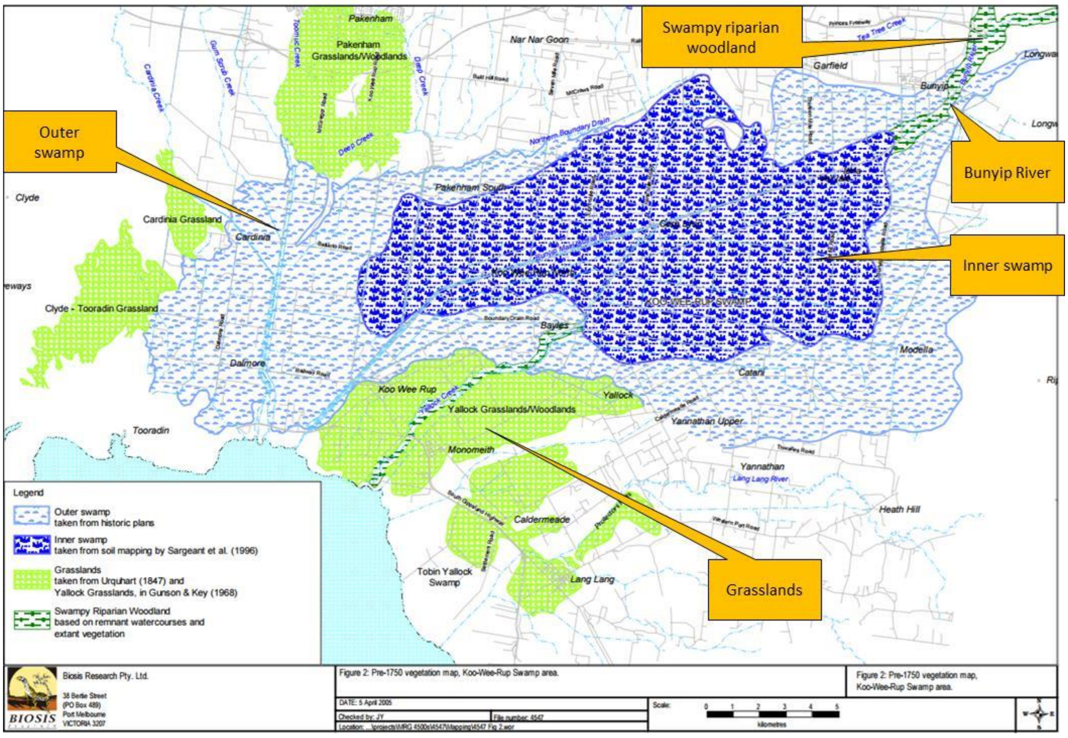

Figure 9 : The extent of Koo Wee Rup Swamp prior to European occupation (Source: Adapted from Biosis (2005)

Although not well documented, there are likely to still be significant Aboriginal cultural values associated with the Swamp, including stories of a fearsome, emu-like Bunyip named Toor-roo-dun, said to lurk in the swamps around Western Port, and for which the Bunyip River is named as well as the township of Tooradin nearby:

*"The Western Port people call the Bun-yip Toor-roo-dun, and a picture of the animal is that of a creature resembling the emu. On the Western Port plains there is a basin of water – never dry, even in the hottest summers – which is called Toor-roo-dun, because the Bun-yip lives in that water. Toor-roo-dun inhabits the deep waters, and the thick mud beneath the deep waters, and in this habit resembles the eel. The natives never bathe in the waters of this basin. A long time ago some of the people bathed in the lake, and they were all drowned, and eaten by Toor-roo-dun" (*Smyth 1878, Andrew Long and Associates 2014).

2.2 Community values

The community places high importance on the Tarago and Bunyip Rivers: for the biodiversity these systems support, particularly the significant number of rare and threatened species and communities present; for their recreation, amenity and liveability, heritage, and tourism values; and for the strong economic and industry values they support within the region.

In no particular order of priority, key values identified through the EWMP consultation process included:

- Provision of important Platypus habitat, particularly in the Tarago River and upper Bunyip River

- The 'Grayling Superhighway' of the Bunyip Main Drain
- Spring fed gullies in the upper Tarago catchment
- Great fishing opportunities
- The high biodiversity values of Cannibal Creek, including threatened species such as Dwarf Galaxids (*Galaxiella pusilla*), Azure Kingfishers (*Ceyx azureus*), Barking Owls (*Ninox conniven*) and Southern Toadlets (*Pseudophryne semimarmorata*)
- Populations of Southern Brown Bandicoots (*Isoodon obesulus*) are found in the lower catchment along the Bunyip Main Drain
- Leadbeater's Possum (*Gymnobelideus leadbeateri*) is found in the forested areas of the upper Bunyip catchment
- The system is the 'lifeblood' of the community, with healthy drains and waterways being good for farmers, and irrigation water in summer supporting many businesses within the region
- There is a strong sense of custodianship of the waterway within the community
- There are good soils for growing potatoes and asparagus
- South of the Gippsland Rail Line, the land provides important areas for dairy farming
- There are strong and engaged Landcare and community groups working to help manage and protect biodiversity values
- There is significant non-Aboriginal heritage and historic values, including waves of multi-cultural settlers to the area, such as Dutch dairy farmers in the 1900s
- There is a growing Citizen Science involvement in the catchment, particularly through Frog Census and Waterwatch actions coordinated by Melbourne Water.

Appendix 4 shows a map of values that were identified by the Tarago and Bunyip Rivers Stakeholder Reference Group[7] during the development of the EWMP.

[7] Members of the Stakeholder Reference Group are detailed in the Acknowledgements section of the EWMP.

Chapter 2 – Values, Condition and Threats

3 Key water-dependent values

The water-dependent values targeted for management through the EWMP closely align with the community's expectations and aspirations for waterways in Melbourne's region, and are based on their importance to the community, the availability of data to assess their condition, and the ability to appropriately represent the range of values found in rivers, estuaries and wetlands (Melbourne Water 2013).

The seven values are:

- Fish
- Platypus
- Vegetation
- Water-dependent birds
- Frogs
- Macroinvertebrates
- Amenity.

These values, their condition and their key flow requirements are summarised below. This information is based on the previous FLOWS studies of the catchment, as well as extensive scientific research and literature review. For further reading on these values, please refer to the extensive reference list at the end of this EWMP.

3.1 Fish

Fish species recorded as being present the Bunyip basin are separated into three groups based on their habitat and migratory requirements:

- **Resident** – Species which require passage only within freshwater and the local environs
- **Migratory** – Which includes species that migrate within freshwater for spawning or dispersal requirements, and species that migrate to and from the sea. This includes anadromous[8] fish, which spend most of their adult lives at sea, but return to fresh water to spawn, and catadromous[9] fish, which live in fresh water and enter salt water to spawn. About 70% of all Australian fish are thought to be migratory
- **Estuarine** – Species which inhabit the brackish and/or marine environment.

Appendix 6 lists all fish species recorded in the Bunyip catchment.

The Tarago and Bunyip environmental FLOWS study reports provide more detailed overviews of a range of the fish species present within the system.

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[8] Anadromous means "upward-running", and refers to the upstream migration of adults.

[9] Catadromous means "downward-running," and refers to the downstream migration of adults.

3.1.1 Species of high value

Fish species of high conservation value are listed in Table 3.

During the development of the EWMP in mid-2017, an Australian Mudfish (*Neochanna cleaveri*) was found in the lower catchment area (Sarah Gaskill Melbourne Water, pers. comm.)

A case study for the Australian Grayling, a priority species in the system for conservation protection, is provided below

Table 3 : High value fish species

Scientific Name	Common Name	FFG	Vic Advisory	EPBC
Prototroctes maraena	Australian Grayling	Listed	Vulnerable	Vulnerable
Galaxiella pusilla	Dwarf Galaxias	Listed	Endangered	Vulnerable
Neochanna cleaveri	Australian Mudfish[1]	Listed	Threatened	
Macquaria australasica	Macquarie Perch[2]	Listed	Endangered	Endangered
Maccullochella peelii	Murray Cod[3]	Listed	Vulnerable	Vulnerable

1 Recently recorded in the southern catchment of the Bunyip

2 Last recorded in 1970 (Tarago River) – Unlikely to be present

3 Last recorded in 1971 (Koo Wee Rup catchment) – Unlikely to be present.

Australian Grayling

Australian Grayling are listed as vulnerable under the Commonwealth Environment Protection and Biodiversity Conservation Act 1999 (EPBC Act), threatened under the Victorian Flora and Fauna Guarantee Act 1988 (FFG Act), and are listed as vulnerable in Victoria according to the Department of Environment, Land, Water and Planning (DELWP)'s Advisory List of Threatened Vertebrate Fauna in Victoria (DELWP 2015a).

Australian Grayling is a diadromous fish, spawning in freshwater in the mid- to lower reaches of coastal rivers sometime in Autumn (April to June), with the adults then returning back upstream. After 12 days, the eggs hatch and the larvae are swept downstream and out to sea, where they remain for 6 months or so. Sometime between October and December the young fish will enter estuaries and migrate upstream, spending the rest of their lives in freshwater reaches.

Recent monitoring and research has found a positive response by Australian Grayling to the provision of environmental flows in the Tarago and Bunyip system. Flow releases provided in Autumn were directly linked to spawning events provided they met certain volume and duration requirements (see Figure 10) (Koster et al. 2013, Amtstaetter et al. 2016).

In the absence of increases in river discharge (greater than the long-term monthly average for the river) Australian Grayling will not spawn. If river discharge increases, but does not go for a long enough duration, again spawning will not occur, providing further evidence that the volume and duration of flows is important to trigger downstream migration and to enable spawning (ARI 2017).

Recent evidence also suggests that juveniles do not necessarily return to the same rivers where they were spawned (Crook et al. 2006, Schmidt et al. 2011), and that populations may persist in some rivers where adults have failed to spawn for several years.

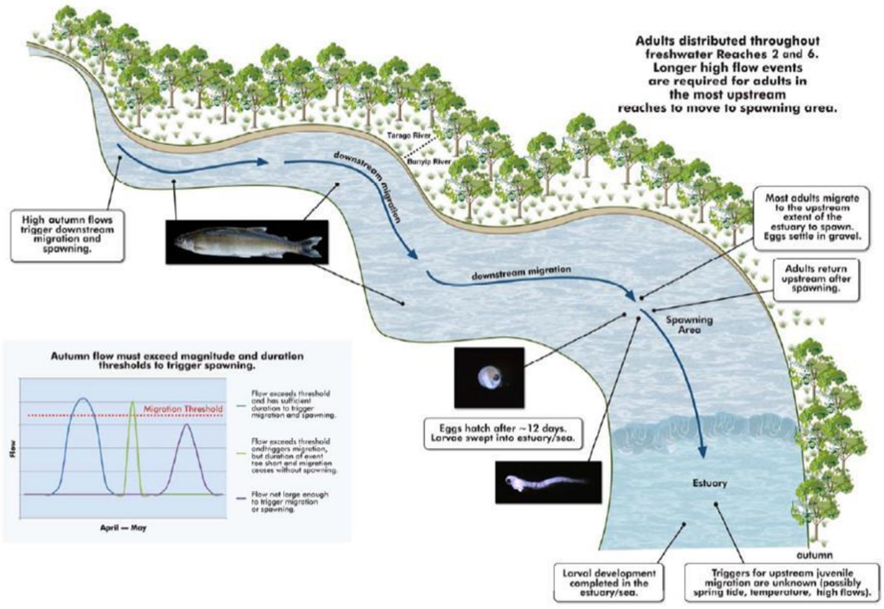


Figure 4-2 Conceptual model presenting the current understanding of the relationship between flow and reproduction for the Australian Grayling in the Bunyip/Tarago system.

Figure 10 : Conceptual model presenting the current understanding of the relationship between flow and reproduction for the Australian Grayling in the Bunyip/Tarago system (Source: (SKM 2013))

Image source for Australian Grayling: By Codman at the English language Wikipedia, CC BY-SA 3.0, https://commons.wikimedia.org/w/index.php?curid=15762561

3.1.2 Condition and management objectives from the Healthy Waterways Strategy

Native fish condition was assessed by Melbourne Water at the catchment scale during the development of the 2013 Healthy Waterways Strategy (HWS), using species richness and nativeness indicators and a range of metrics from an independent Sustainable Rivers Audit (SRA) (Melbourne Water 2013).

Figure 11 summarises condition and high level management objectives for fish, broken down into the upper and lower catchment management units.

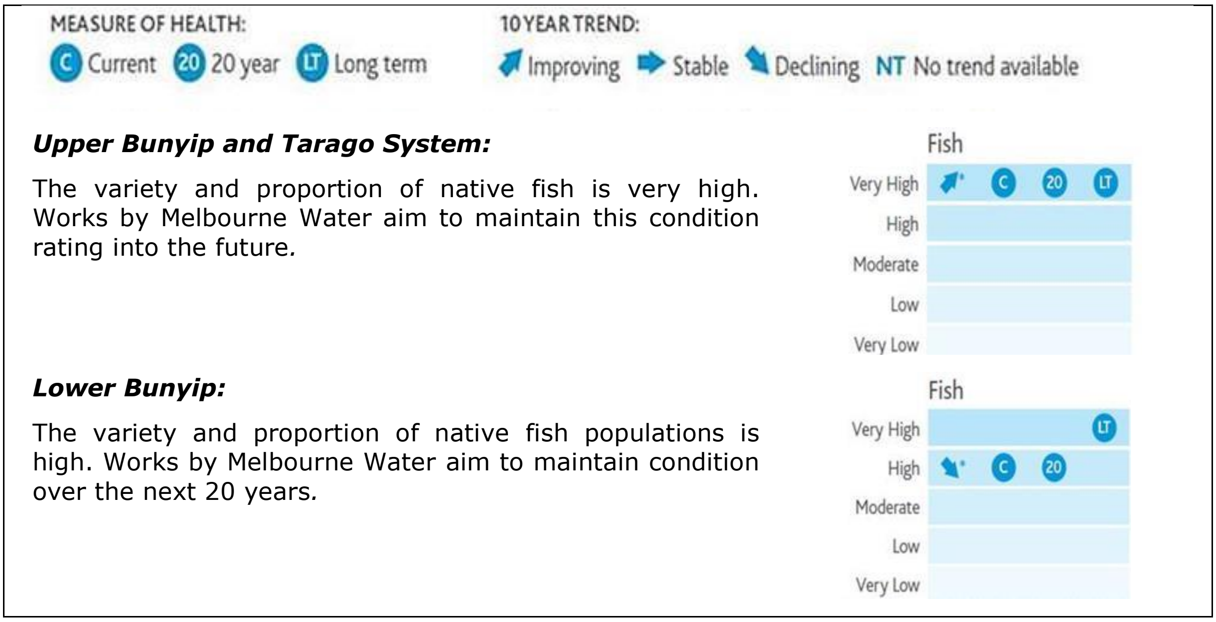


Figure 11 : Condition and HWS management objectives for fish (Source: Adapted from Melbourne Water (2013))

3.1.3 Key flow requirements

Table 4 summarises some of the key flow requirements for fish, with a range of examples provided.

Table 4 : Key flow requirements for fish, by habitat and migration preference

Habitat / migratory requirements	Key flow requirements
Migratory fish	• Migratory fish require a range of different flows for their general lifecycle requirements, and for movement within and between their habitats. • For example, Australian Grayling need medium/high flows over a long duration in autumn to facilitate their downstream migration, to cue spawning, and to carry their eggs and larvae out to sea. Individuals live for 3-5 years, but females do not mature until they are two years old (McDowall 1996), and do not release their eggs without high autumn flows. • This means that if these flows do not occur for three or four successive years, an entire population of the species may disappear from a waterway without reproducing (O'Connor and Mahoney 2004).
Non-migratory fish	• Non-migratory fish need flows to provide them with habitat, food, breeding opportunities and protection from predators. Flows may also provide cues for spawning for some of these species. • For example, River Blackfish can be found in both slower and faster flowing waters but it prefers to stay in low-velocity, highly sheltered pools (Koehn *et al.* 1994, Koster and Crook 2008). It relies on flows and freshes to inundate instream hard surfaces such as hollow logs to lay their eggs. • High flows are risky for their reproductive success because they can scour away eggs and wash their larvae away (Koster and Crook 2008).
Estuarine and marine fish	• Freshwater flow and tidal patterns are the principal physical variables determining the characteristics of an estuary, characterised by a salinity structure that varies in relation to the amount of freshwater flow an estuary receives (Kurup et al. 1998). • Some freshwater fish species may move downstream into an estuary during periods of high flow, and some marine species may move upstream

Habitat / migratory requirements	Key flow requirements
	into estuaries and/or freshwater reaches with the incoming tide (Arundel and Barton 2007). • Other species, such as Australian Grayling, Eels and Galaxiids, migrate between the freshwater, estuarine and marine environments at different times of the year. • Flows from the Bunyip River provide nutrients and sediment into Western Port, which stimulate phytoplankton (algae) productivity, which then feeds zooplankton, and which then provides food for fish larvae. If there isn't sufficient food for fish larvae they are unable to grow and survive to breeding age. • Evidence suggests that there is a strong correlation between high sediment input into Western Port and seagrass dieback, which has reduced the availability of nursery areas, food sources and shelter for a large number of fish species such as King George Whiting, and a subsequent decline in these species within the Bay (Jenkins 2010).

River Blackfish

Recent baseline fish sampling findings are of concern for River Blackfish, which show low population densities and poor or non-existent recruitment levels in Tarago River Reach 2 and Bunyip River Reach 4 (apart from the two most upstream sites in Bunyip State Park) (Ecology Australia 2017). The causes for this decrease are not known, and environmental flow requirements will need to be thoroughly reviewed and compared against the existing flow recommendations to determine if a different set of flow requirements need to be established specifically for River Blackfish (Ecology Australia 2017). This approach will be complimentary to other existing intervention programs for Melbourne Water, such as willow removal and woody debris reintroduction, which cumulatively may be critical to ensure the long term viability of River Blackfish populations beyond the somewhat protective boundaries of the Bunyip State Park (Ecology Australia 2017).

3.1.4 Management actions

Value/issue	Threat	Implication	Actions
Australian Grayling	• Gaps in knowledge still exist regarding Australian Grayling ecology and links with flow	• Inadequate flow regime to maintain resilience of the species Consequent reduction in abundance and distribution or possible local extinctions	• Melbourne Water will conduct further research to better understand the influence of flow on immigration and upstream dispersal. • Melbourne Water will implement the Australian Grayling recommendations from ARI (2017).
River Blackfish	• River Blackfish numbers are declining, with evidence of poor recruitment. • Climate change could exacerbate threats.	Loss/extinction of the species from the catchment	• Melbourne Water will review environmental flow requirements for River Blackfish and update seasonal planning as necessary. • Complementary actions to protect and improve habitat availability and quality.

3.2 Platypus

The platypus (*Ornithorhynchus anatinus*) is one of only five species of egg-laying mammals in the world, and the only species within the family Ornithorhynchidae. It is one of the most evolutionarily distinct mammals on Earth and is an irreplaceable component of Australian and global biodiversity (Bino *et al.* 2015). The platypus is considered "of least concern" under current IUCN red listing (Lunney *et al.* 2008a), but the national conservation status of the species has been elevated to 'Near Threatened' in the CSIRO's 'Action Plan for Australian Mammals' (Woinarski *et al.* 2014), in recognition that its numbers have been declining in many areas over the past few decades and it has already disappeared from some catchments.

Melbourne Water is committed to protecting and improving platypus habitat through its Melbourne Water Urban Platypus Program (MWUPP). Since 2002, the MWUPP has monitored the presence of platypus in the Bunyip and Tarago catchments at Labertouche Creek and the lower Tarago River. Over this time, the abundance of platypus has declined substantially, particularly during the period of the Millennium Drought, although the population remains a strong-hold for the species in the Western Port catchment (cesar 2016). Anecdotal evidence suggests that platypus may also be found along the lower Bunyip River, with Tarago-Bunyip Stakeholder Reference Group members commenting they regularly see platypus along the full length of the River.

3.2.1 Condition and management objectives from the HWS

Although the platypus remains widely distributed across its natural range in Australia, scientists are becoming increasingly concerned at its downwards trajectory. Monitoring is showing that in many areas within its natural range, platypus populations are decreasing, to the point of extinction in some catchments (Lunney *et al.* 2008a). The platypus is considered of "least concern" under IUCN red listing protocols, but its current conservation status in Australia was recently changed to "Near Threatened" under the CSIRO's 'Action Plan for Australian Mammals (Lunney *et al.* 2008b, Woinarski *et al.* 2014).

Figure 12 provides an overview of platypus condition and HWS management objectives for the Tarago and Bunyip systems.

Upper Bunyip and Tarago System:

The lower Tarago River has the highest known abundance of platypus in the Westernport catchment, but platypus populations have declined significantly over the past 200 years. The Millennium drought is considered a key reason for the recorded decline over that period. The population condition is rated as very low. Works aim to improve condition to low over the next 20 years, and to moderate in the long term.

Lower Bunyip:

A decline in platypus numbers has occurred due to significant alteration and disturbance of waterways. The population of platypus in Lang Lang River is small and following many years of drought, numbers are considered to be critically low. Works aim to stabilise this population to allow for improvement over the long term.

Figure 12 : Condition and HWS management objectives for platypus (Source: Adapted from Melbourne Water (2013))

Opera House Nets

Sadly, during the development of the EWMP in 2017 almost half of the platypus population of Labertouche Creek was wiped out after being caught and drowning in two illegal opera house nets placed in farm dams near Labertouche Creek. This population was considered one of the healthiest in the catchment, and it had been on the way towards recovering from the impacts of the Millennium Drought. It now remains to be seen if the population will recover to pre-drought condition. Ongoing monitoring through the MWUPP will be used to track the impacts of this kill event on the population.

Scientists are recommending that the design of the nets commercially available in Victoria be changed so that they allow easier escape by platypus if they become trapped. Melbourne Water supports this initiative.

3.2.2 Key flow requirements

Platypus need access to freshwater habitats to forage, and river banks to dig their burrows. Their ideal habitat includes rivers or streams with earthen banks consolidated by the roots of native vegetation, macroinvertebrate food sources, cobbled or gravel substrates, overhanging shady vegetation, and a sequence of pools and riffles (Grant and Fanning 2007). They can occupy lakes and farm dams however, and can also sometimes be found in streams quite degraded by human activities (Grant and Fanning 2007).

Acoustic telemetry was used to track resident platypuses in the Tarago River before, during, and after scheduled environmental flows in Autumn of 2015 (cesar 2015). This work found there was no evidence of negative impacts on platypuses from the environmental flow event, including several tagged juveniles, which are considered the most vulnerable demographic group for the species. The researchers also found that:

- Platypuses increased their activity and movements in response to increased flows generated by the release of environmental water
- Low water levels experienced before the environmental flow event resulted in decreased habitat availability, reduced connectivity along the waterway and increased predation risk for platypuses. These conditions appeared to inhibit platypus movements.
- During the environmental flow event, platypuses displayed a lower site fidelity, moving between areas more frequently, and they had higher nightly foraging distances (cesar 2015).

In 2016 Melbourne Water commissioned a project to review the latest scientific literature and explore a range of factors important to platypus management in the Greater Melbourne region, with particular emphasis on the species' key flow requirements (Jacobs *et al.* 2016). Figure 13 shows a conceptual model from this review, indicating the benefits and risks to platypus of different flow components over a twelve month period. The conceptual model is based on a stylised flow series over time and uses a risk classification system (high, medium, low) to depict the benefits or risks to platypus of these flow components at various times of year. The key risk factors associated with flow requirements are the ability of the animal to find sources of food, to shelter from predators and strong currents, and to ensure its reproductive success by protecting young platypus.

A description of each numbered risk point is provided below Figure 13.

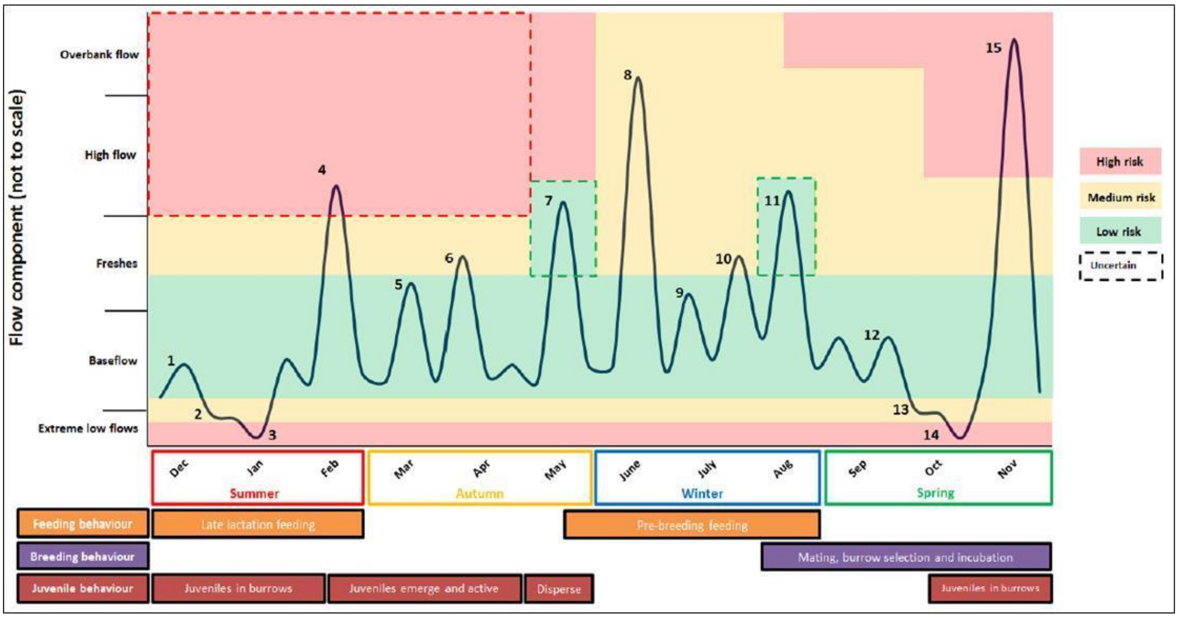


Figure 13 : Stylised flow series indicating the benefit and risk to platypus over the year (Source: Jacobs *et al.* (2016)

In explanation:

1. **Moderate summer/autumn baseflow is considered low risk**: Platypus need to feed on a daily basis all year and moderate baseflow supports macroinvertebrate production and provides adequate water depth and connectivity along channel for efficient foraging (adults and juveniles). Stable flows from December to February also support platypus reproduction; the energy needs of lactating females peak from December to early February.

2. **Low summer/autumn baseflow is a medium risk**: Macroinvertebrate productivity is reduced at low baseflow, limiting food resources. Can be tolerated for short periods but extended periods can be detrimental.

3. **Extreme low flows are high risk**: Increased risk from predation due to increased overland movement or movement through a dry channel or shallow water. Insufficient macroinvertebrate productivity to support reproduction or maintain good adult condition.

4. **Summer/autumn high flows are high risk**: Although small to moderate summer freshes are generally beneficial (see 5), flows that result in water depth increasing significantly compared to spring baseflow (e.g. rise greater than 1 m) can inundate breeding burrows, causing young animals to drown (highest risk period is December-early February). Juveniles that are just learning to swim may also drown or be swept downstream in flows of this magnitude (highest risk period is late January-early March). High flows should therefore be avoided if possible in these months (but see 9).

5. **Occasional summer/autumn freshes are low risk**: Freshes may benefit platypus by promoting exploratory behaviour, encouraging individuals to discover new resources and habitats. Freshes also maintain habitat quality by scouring fine sediment from pools and riffles and can contribute to macroinvertebrate productivity. Although foraging efficiency may decrease during higher velocity flows, the net effect of summer/autumn freshes should generally be positive to very positive for this species.

6. **Frequent summer/autumn freshes are a moderate risk**: Foraging efficiency is likely to be

reduced during freshes and therefore very frequent fresh events should be avoided.

7. **Late autumn high flow is a possible low risk**: It is possible that dispersal of first-year juveniles may be promoted by a rise in flow (particularly from a low baseflow) in late autumn (May). However, appropriate studies have not yet been carried out to determine whether this actually occurs in nature.
8. **Winter high flow and overbank flows (medium risk):** Floods and overbank flows can be important for waterway productivity (e.g. carbon input). However, very high flows also increase metabolic demand in foraging and can scour macroinvertebrate food sources, damage burrows and even result in platypus deaths. Adult platypus can use slower flowing habitats to forage during floods insofar as these are available and are generally expected to survive such events, but no positive benefit is expected to accrue to them in the immediate term.
9. **Occasional winter/spring freshes (low risk)**: The benefits to habitat maintenance of winter/spring freshes are similar to those previously described for summer/autumn freshes (see 5).
10. **Frequent winter/spring freshes (low risk):** As with frequent summer/autumn freshes (see 6), the reduction in foraging efficiency during freshes means that frequent freshes represent a moderate risk.
11. **Late winter /spring freshes (low risk):** A high flow event in late winter or very early spring (August-early September; shortly before a breeding female selects her nesting burrow), may result in her choosing or building a burrow that is located higher on the bank than might otherwise be the case. This in turn may reduce the likelihood that the burrow is later inundated if flow increases markedly thereafter (see 4). However, appropriate studies have not yet been carried out to determine whether this actually occurs in the wild.
12. **Moderate winter/spring baseflow (low risk):** Periods of stable baseflow providing good platypus foraging conditions are important as females attempt to gain weight in preparation for breeding.
13. **Low winter/spring baseflow (medium risk):** As described in 2, macroinvertebrate productivity is reduced when baseflow is low, limiting food resources. This is particularly a problem for lactating females, given they have high energy requirements. Platypus are expected to survive short periods of reduced baseflow but extended periods will be detrimental.
14. **Extreme low winter/spring baseflow (high risk):** As described in 3, extreme low flows are a risk both as a result of increased predation and lower food resources.
15. **Spring high flow and overbank flows (high risk):** Very high or overbank flows present a very high risk to reproduction, due to inundation of burrows containing eggs and/or nestling juveniles (Jacobs *et al.* 2016).

3.2.3 Other mammals

In addition to platypus, a range of other mammals with high conservation value have been recorded near the Tarago and Bunyip Rivers, with varying degrees of dependency on these waterways for their habitat, shelter and food needs (Table 5).

Table 5 : Mammal species of high conservation value

Scientific Name	Common Name	FFG	Vic Advisory	EPBC
Gymnobelideus leadbeateri	Leadbeater's Possum	Listed	Endangered	Critically Endangered
Petauroides volans	Greater Glider		Vulnerable	Vulnerable
Dasyurus maculatus	Spot-tailed Quoll	Listed	Endangered	Endangered

Scientific Name	Common Name	FFG	Vic Advisory	EPBC
maculatus				
Isoodon obesulus obesulus	Southern Brown Bandicoot	Listed	Near threatened	Endangered
Sminthopsis leucopus	White-footed Dunnart	Listed	Near threatened	
Mastacomys fuscus mordicus	Broad-toothed Rat	Listed	Endangered	Vulnerable
Antechinus minimus maritimus	Swamp Antechinus	Listed	Near threatened	Vulnerable
Cercartetus nanus	Eastern Pygmy-possum	Rejected	Near threatened	
Phascogale tapoatafa	Brush-tailed Phascogale	Listed	Vulnerable	

Two of these species, the Leadbeater's Possum and the Southern Brown Bandicoot are discussed in Case Studies below because significant efforts are being undertaken to protect these species from extinction and they have also been identified by the Tarago-Bunyip Stakeholder Reference Group as important species in the region.

Possible water dependency requirements are briefly summarised for both species, but actions for their management by Melbourne Water and other agencies will predominantly focus on complementary catchment actions due to their likely lesser dependence on specific flow components, and constraints in providing environmental water to the areas of the system where they are found.

Leadbeater's Possum

Presumed extinct until it was rediscovered near Marysville in 1961, Leadbeater's Possum is one of the most critically endangered species in Australia, with estimates that there are now less than 1500 remaining in the wild (DEPI 2014a). Important populations of the species are found near the headwaters of the Bunyip and Tarago Rivers

Arboreal (tree dwelling) marsupials such as Leadbeater's Possum require a complex forest structure for their habitat, including large old hollow-bearing trees for nesting (commonly found within riparian gullies) and multiple layers of vegetation in the mid-storey and understorey to provide transport routes for their movement within the forest (Lindenmayer et al. 2013). Riparian vegetation also provides an important food source for Leadbeater's Possums, such as manna, gum and sap exuded by some trees (usually from *Acacia*, *Leptospermum* and *Melaleuca* species) (Lindenmayer et al. 2013).

A recent study by Isaac *et al.* (2014) looking at the impacts of urbanisation on arboreal marsupials in the Greater Melbourne area found that regardless of their position along the urbanisation gradient, riparian habitats proved important in predicting potential habitat because these habitats are often the last remnants standing of pre-disturbance habitat. This demonstrates that even in the most urbanised environments, intact riparian habitats may act as refuges for displaced species (Isaac *et al.* 2014).

There is also strong evidence that hydrology has an influence on the condition and quality of Leadbeater's Possum habitat. Recent research has found that an altered water regime (in this case prolonged waterlogging) is a primary driver for vegetation dieback and poor regeneration in a key area of habitat for the species (Yellingbo), particularly for Mountain Swamp Gum (Greet 2014).

This work highlights the importance of maintaining riparian vegetation in the Tarago and Bunyip catchments because it provides important Leadbeater's Possum habitat in the headwater areas. Although environmental flows cannot be provided in these upper catchment areas, being largely unregulated, it will be important to ensure that the impacts of land use change are minimised, to not only protect hollow-bearing trees, but to also protect the hydrological regime that helps to maintain the species' riparian habitats.

Image source: https://commons.wikimedia.org/wiki/File:Leadbeater%27s_Possum_called_George_-_taxidermied_01.JPG. Licence: Creative Commons Attribution-Share Alike 3.0 Unported

Southern Brown Bandicoot

The Southern Brown Bandicoot has undergone a dramatic decline in distribution and abundance across its range in south-eastern mainland Australia (DEPI 2014b). Human activities such as agriculture, urban and industrial development and the introduction of predators such as foxes, dogs and cats have contributed to the decline of this species.

Southern Brown Bandicoot has been recorded at numerous sites within the Bunyip catchment, and is highly valued by the community. The species is found in linear and remnant strips and patches of indigenous and exotic vegetation, often recorded along road reserves, rail lines, drainage lines and watercourses. This type of habitat is found along the Bunyip Main Drain.

Prior to European occupation, Southern Brown Bandicoots would have been common within the catchment, particularly associated with Koo Wee Rup Swamp because the species generally prefers habitats supporting heaths, heathy woodlands and forests or other vegetation communities that provide a thick ground cover over sandy well-drained soils (Haby et al. 2013). Previous FLOWS studies of the Tarago and Bunyip Rivers did not assess or provide flow recommendations for Southern Brown Bandicoots. However, flows which support the extent and quality of riparian vegetation along the Bunyip and Tarago rivers may assist the species by maintaining critical habitat and by providing opportunities to recolonise other suitable areas, through connection of habitat corridors along the waterways.

3.2.4 Management actions

Value/issue	Threat	Implication	Actions
Opera House Nets	Illegal use of opera house nets in public waters in Victoria, and Melbourne Water has had drastic impacts on platypus	Local extinction of platypus	Melbourne Water will engage and communicate with communities to ensure greater awareness of the consequences of using these nets.
Platypus flow requirements	New knowledge not incorporated into platypus management strategy	• Drowning of platypus babies • Poorer habitat quality and availability • Reductions in population distribution and abundance and possible local extinctions	• Melbourne Water will incorporate new platypus knowledge in to the environmental watering program for the Tarago/Bunyip system and adjust flow provisions where identified. • Platypus knowledge will be further reviewed and incorporated into the next review of the environmental FLOWS study.

3.3 Vegetation

The Bunyip and Tarago Rivers flow through three different bioregions: Gippsland Plains; Strzelecki Ranges; and Highlands-Southern Fall (Figure 14).

The **Gippsland Plain** bioregion includes flat, low-lying coastal and alluvial plains with a gently undulating terrain, and is dominated by barrier dunes and floodplains and swampy flats (VEAC 2010). The bioregion retains native vegetation of a fragmented pattern, reflecting a variety of land-use histories. Less than 1% of the bioregion is considered intact, with most of the region heavily modified and only a quarter of the original extent of native vegetation remaining, half of which is on public land (VEAC 2010).

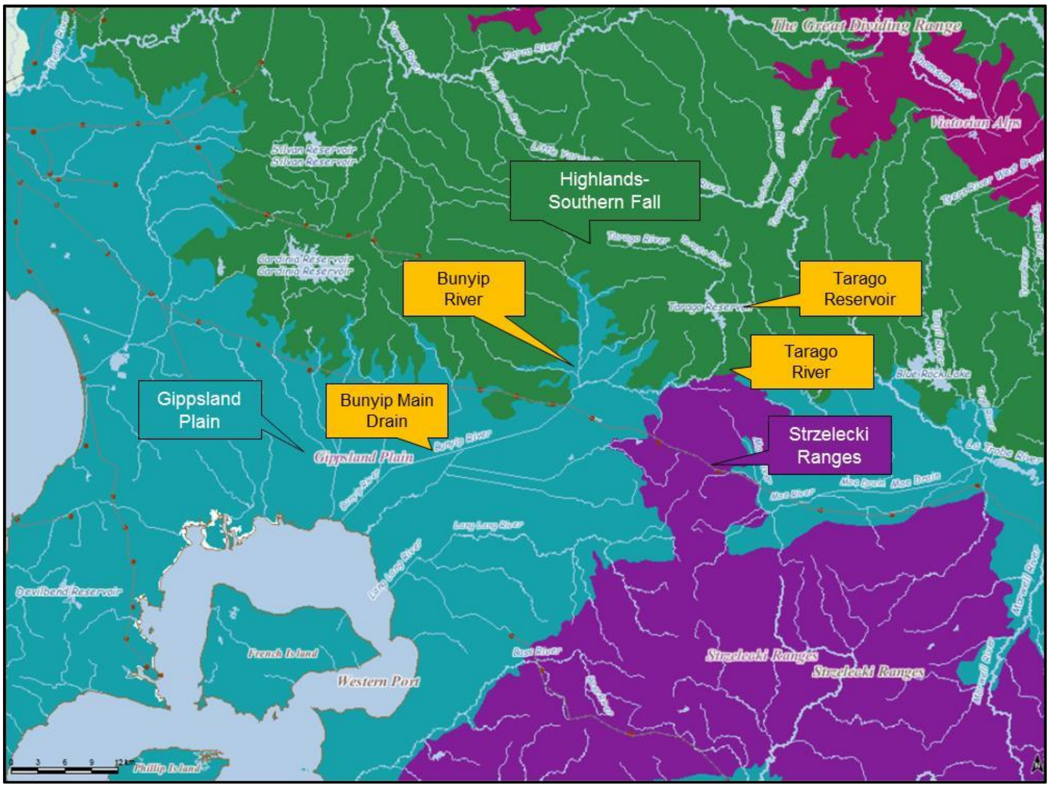


Figure 14 : Bioregions relevant to the Bunyip and Tarago River catchments catchment (Source: Adapted from DELWP Biodiversity Interactive Map (DELWP 2017))

The draining of Koo Wee Rup Swamp extensively modified the hydrology and vegetation of this wetland. It is not well known, but researchers now believe the inner Koo Wee Rup Swamp was an extensive treeless reed swamp growing on an extensive peat layer, with bodies of open water (Biosis 2005). The fringes were dense Swamp Paperbark (*Melaleuca ericifolia)*, possibly giving an impression that the scrub occurred throughout (Biosis 2005). The core of the Swamp is thought to have been dominated by reeds and rushes, particularly Common Reed (*Phragmites australis*). Native grassland was extensive on the fringes and floodplain surrounding the Swamp, much of which was treeless or only lightly wooded with Blackwood (*Acacia melanoxylon*). Aboriginal burning practices are thought to have maintained these grasslands and open woodlands, until European occupation and the subsequent cessation of these practices encouraged a more extensive coverage of Blackwood (Biosis 2005).

Near the estuary, the areas of saltmarsh could possibly represent one of the most floristically diverse coastal saltmarshes in the world (Boon 2011). Associated with Mangrove Shrubland EVCs along the coastline, the White Mangrove (*Avicennia marina ssp australasica*) growing at Western Port is close to the most southerly population of mangroves in the world at Corner Inlet (Dittmann 2011).

North of the Gippsland Rail Line, the **Highlands-Southern Fall** bioregion is part of the Great Dividing Range and has moderate to steep slopes, high plateaus and alluvial flats along the main valleys. One third of the bioregion is fragmented, but extensive areas of native vegetation do remain, with almost half of this on public land (VEAC 2010). A moderate proportion is within conservation reserves (8.4%), many of which extend into the largely intact landscape (VEAC 2010).

The northern most tip of the **Strzelecki Ranges** bioregion directly abuts the Tarago River downstream of the Tarago Reservoir. This bioregion is heavily modified and has been heavily cleared.

3.3.1 Condition and management objectives from the HWS

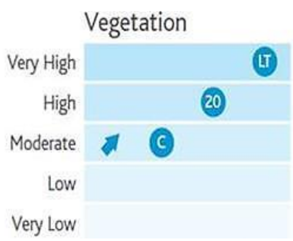
In the upper reaches of the Tarago and Bunyip Rivers, where land use change is more limited, much of the original vegetation remains intact and is continuous. However in the agricultural and urban areas in the lower catchment, the riparian zone is almost completely cleared and is dominated by introduced species. The clearing of land for agriculture has been most intense in the low-lying floodplains across where Koo Wee Rup Swamp once was, and many of the EVCs in this area are now considered endangered.

Figure 15 shows the condition and high level management objectives for vegetation in the Tarago and Bunyip catchments, as detailed in the HWS.

Table 6 provides an overview of the vegetation noted at each reach during the 2007 FLOWS study (EarthTech 2006b), including an assessment of condition. The reaches are categorised into the freshwater sections found north of the Gippsland Rail Line (Reaches 1 to 5); the mostly freshwater section found south of the Rail Line (Reach 6); and the Bunyip Estuary (Reach 7).

Upper Bunyip and Tarago System:

The upper reaches of waterways are largely within state parks, with vegetation condition declining in lower reaches. Overall condition is rated as moderate with works over the next 20 years aiming to improve this to high, and very high in the long-term.



Lower Bunyip:

Vegetation has been subject to widespread clearing and condition is very low. Works concentrating on streamside revegetation will aim to improve condition to moderate over the next 20 years.

The presence of levees and the need to maintain hydraulic capacity will limit the ability to achieve high vegetation on all waterways in this system.

Figure 15 : Condition and HWS management objectives for vegetation (Source: Melbourne Water (2013))

Table 6 : Vegetation associated with each reach of the Tarago and Bunyip Rivers

Reaches	Condition
Freshwater reaches north of Gippsland Rail	**Reach 1** Vegetation within the Upper Tarago River is relatively intact, with the majority of the river flanked by continuous riparian forest. A valley at the downstream

Reaches	Condition
Line	end of the reach is less confined and has been cleared for grazing. For the majority of the reach, the river is flanked by continuous riparian forest dominated by an overstorey of Manna Gum. A good diversity of understorey shrubs, ferns, herbs and grasses is present along the banks below Pedersen Weir. The steep bed, rocky substrate and flows prevent vegetation growing in the bed of the river. **Reach 2** Vegetation within the reach of the Tarago River below the Reservoir has been highly disturbed and much of the riparian zone has been cleared for agriculture. Despite the extensive modification, remnant vegetation is present including large trees, shrubs and macrophytes. Exotic plant infestation including pasture grass is prevalent in this reach. **Reach 3** Sections of Labertouche Creek are flanked by continuous remnant riparian vegetation within the lower cleared agricultural land. In other areas, the native overstorey is sparse and understorey is largely absent. The remnant vegetation alternates between Riparian Forest and Swampy Riparian Woodland, which are considered Vulnerable and Endangered respectively within the Gippsland Plain Bioregion. **Reach 4** Remnant riparian vegetation abuts most of the upper and mid sections of the Upper Bunyip River. This remnant vegetation is predominantly Swampy Riparian Woodland which has a conservation status of Endangered within the Gippsland Plain Bioregion. The upper sections of this reach contain high quality vegetation with minimal weed cover. Instream vegetation, including Water Ribbons and Common Reed, is abundant and healthy. Swampy streamside vegetation is present and includes a diverse suite of aquatic and semi-aquatic flora lifeforms. **Reach 5** Vegetation within Cannibal Creek is dominated by Riparian Thicket in the upper sections and Swampy Riparian Woodland in the lower sections. The low lying vegetation is dominated by ferns and sedges and is likely to be regularly inundated. Instream aquatic plants are also abundant at this reach. Swampy Riparian Woodlands vegetation shows a good diversity of species and habitats despite stock pressure (grazing and pugging). The channel contains a healthy variety of aquatics, rushes, sedges and reeds below an open canopy of Tea-tree, Paperbark, Wattle and Swamp Gum.
Freshwater reaches south of Gippsland Rail Line	**Reach 6** This reach has been totally modified and virtually all of the swampy scrub and woodlands have been cleared. The deepened constructed and natural channel can no longer support the swampy vegetation communities that once existed. This channel is now very deep and the constructed banks have been revegetated with dryer riparian species. Blackberries and other weed species are prevalent along the banks.
Bunyip Estuary	**Reach 7** Estuarine vegetation is influenced by the highly dynamic system, in which virtually all of the water which enters on a flood tide is removed in the subsequent ebb. Above the highway bridge the riparian zone contains plant species tolerant of fresh to brackish conditions (e.g. *Phragmites* and *Juncus* spp). Below the bridge there are saltmarsh communities in lower lying areas – particularly along the eastern bank. Mangrove seedlings occur along this section but mature trees are confined to the first 100m upstream of the entrance.

For more detail about the vegetation of each reach, please refer to the FLOWS study reports (EarthTech 2006b, c, a, SKM 2013).

3.3.2 Vegetation species and communities of high value

Remnant vegetation has survived despite the highly disturbed nature of land use in the Tarago and Bunyip catchments. Some key plant species and communities of high conservation value include:

- The endangered Strezlecki Gum (*Eucalyptus strzeleckii*) along Labertouche Creek and the Tarago River, and the Yarra Gum (*Eucalyptus yarraensis*)
- Green Scentbark (*Eucalyptus fulgens*) and Tree Geebung (*Persoonia arborea*) along the upper reaches
- Shrubs such as Toothed Leionema (*Leionema bilobum serrulatum*) and Long Pink-bells (*Tetratheca stenocarpa*), and the Gully Grevillea (*Grevillea barklyana*), which is confined to an area of about 50 km^2 of State Forest and State Park in the Tarago River headwaters and also within the Bunyip State Park.
- Flowering plants such as the Green-striped Greenhood (*Pterostylis chlorogramma*), Tall Astelia (*Astelia Australiana*), and ferns such as the Filmy Maidenhair (*Adiantum diaphanum*).

Appendix 6 lists plant species of high conservation value recorded in the VBA database for the Tarago and Bunyip catchment.

3.3.3 Key flow requirements

To improve or sustain the health of vegetation, the following flow requirements are generally recommended:

- Varying flow patterns help to sustain riparian and floodplain vegetation and create a zonation of species, from aquatic and semi aquatic, to flood dependant and flood tolerant. This provides a variety of habitats for flora and fauna species and communities
- High and overbank flows help to prevent the contraction of riparian zone vegetation
- Prolonged flows can help to suppress particular weed species or prevent unnatural vegetation colonisation of instream bars
- High flows can be used to scour out the bed or bars of a stream to prevent over-colonisation of vegetation and/or provide sediment deposition for vegetation regeneration
- Overbank flows may be recommended to water floodplain vegetation, helping to maintain lateral connectivity and nutrient cycles between the instream river habitat and the riparian/terrestrial zone. Overbank flows can also help to trigger germination, regeneration or transport of plant propagules and seeds
- In estuarine environments, a reduction in freshwater flow can increase the degree of marine influence which may have an effect on plant species colonising this area. Low discharges may also lead to increased sedimentation in the estuary, causing an expansion of mangroves and possibly saltmarsh, into the estuary.

3.4 Water-dependent birds

Water-dependent birds have become specialised to certain wetland or river habitats, and may depend on regular access to freshwater or brackish water for many of their lifecycle processes such as feeding or breeding, or aspects of their lifecycle are triggered by flows and inundation patterns. Streamside, wetland and estuarine birds are included within the definition of water-dependent bird for the EWMP, as are some seabirds.

The Tarago/Bunyip waterways provide important breeding and feeding habitat for species such as the Musk Duck[10] (*Biziura lobata*) and the Hardhead[11] (*Aythya australis*), and the riparian areas of the upper Bunyip River may provide habitat for the critically endangered Helmeted Honeyeater (*Lichenostomus melanops cassidix*) (see Case Study below). The Black Bittern (*Ixobrychus flavicollis australis*) generally relies on dense vegetation found around wetlands and waterways for cover and protection during breeding, moulting and daily foraging. Other birds, such as the Yellow-billed Spoonbill (*Platalea flavipes*), rely on variations in natural water depths and flows to trigger breeding.

Water-dependent birds are an important component of aquatic systems and they can exert a strong influence on their ecological function. Changes in water-dependent bird populations may cause associated changes in other wetland biota, which can then create disturbance impacts throughout aquatic food webs and affect nutrient dynamics (Hansen *et al.* 2015).

3.4.1 Condition and management objectives from the HWS

There is little information available on the condition and distribution of waterbird species in the Tarago and Bunyip River catchments, or the effects of river regulation and reduced inundation of freshwater wetlands and billabongs on their distribution and abundance. The HWS does however provide a brief synopsis of waterbird condition and high level management objectives, which is summarised in Figure 16.

3.4.2 Bird species of high value

Appendix 6 lists bird species of high conservation value recorded for the Tarago and Bunyip Rivers, including those protected under international treaties.

3.4.3 Key flow requirements

Little is known of the effects of river regulation and changing flow regimes on the distribution and abundance of water-dependent birds in the Tarago and Bunyip system. However, long-term monitoring data collected through the efforts of researchers and local community groups near Western Port can be used to inform our knowledge of the more general trends and trajectories for water-dependent bird species in the area (Purdey and Menkhorst 2015).

Waterbird population trends have been measured over nearly 40 years in Western Port, and have shown consistent patterns over time across multiple species (Hansen *et al.* 2015). Over this time period many species have declined, thought to reflect diminishing wetland availability, local reductions in fish prey, increased predation pressure and changes in inland wetland resources (Hansen *et al.* 2015). Decreases in fish-eating birds are also thought to coincide with substantial losses of seagrass in Western Port (Blake & Ball 2001). The loss of the seagrass beds in the 1970s and early 1980s is likely to have affected many bird species through changes in intertidal food web dynamics, including invertebrate prey availability and the loss of fish habitat (Hansen *et al.* 2015).

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[10] Listed as Vulnerable in the Advisory List of Threatened Vertebrate Fauna in Victoria: 2013 list (DSE 2013)

[11] Listed as Vulnerable in the Advisory List of Threatened Vertebrate Fauna in Victoria: 2013 list (DSE 2013)

Upper Bunyip and Tarago System:

Based on streamside bird data, the variety and proportion of native bird species is moderate. Works focusing on improving habitat aim to maintain this condition over the next 20 years with improvements in the long term.

Lower Bunyip:

Bird condition is based on streamside birds only. The number and variety of species is very low. Works to improve habitat aim to raise this condition to low over 20 years and moderate in the long term.

The long-term condition will be limited by the lack of large forested areas as habitat.

Figure 16 : Condition and HWS management objectives for water-dependent birds (Source: Adapted from Melbourne Water (2013))

The Tarago-Bunyip Stakeholder Reference Group also identified the Helmeted Honeyeater as a significant value of the upper catchment. Its possible flow requirements are summarised in the Case Study below, although more research is needed to confirm the relationship between the condition of Helmeted Honeyeater and its flow requirements, if any.

Helmeted Honeyeaters

A small population of the critically endangered Helmeted Honeyeater has been reintroduced via a captive breeding program to the Bunyip State Park near the upper reaches of the Bunyip River. The Helmeted Honeyeater inhabits dense riparian and swamp forests, often dominated by Manna Gum (*Eucalyptus viminalis*), Swamp Gum (*Eucalyptus ovata*) and Mountain Swamp Gum (*Eucalyptus camphora*) with a dense understorey and sedges and tussock grasses (DEWHA 2009). The species was most likely common in the Koo Wee Rup Swamp area before it was drained and vegetation removed.

Habitat degradation is a serious threat to the Helmeted Honeyeater. Die-off of riparian stands of eucalypts and melaleucas within their preferred habitat in the last decade has significantly reduced the area of available habitat for important breeding colonies. Other threats to their habitat include the lack of regeneration of the Swamp Woodland, and the spread of tall grass species including the Common Reed (*Phragmites australis)* and weed species such as Reed Canary Grass (*Phalaris arundinacae)* and Reed Sweet-grass (*Glyceria maxima)* (DEWHA 2009).

Recent research has found that an altered water regime (in this case prolonged waterlogging) is a primary driver for vegetation dieback and poor regeneration in a key area of habitat for the species (Yellingbo), particularly for Mountain Swamp Gum (Greet 2014).

Although environmental flows cannot be used to directly water its habitat in the upper Bunyip catchment, it will be important to understand the broader land use change processes that may be affecting the hydrological regimes of the area. Further studies are needed to unravel the relationship between changed hydrological regimes, nutrient levels, pathogens and insect outbreaks (DEWHA 2009).

Image source: *By Dylan Sanusi-Goh - Own work, CC BY 4.0, https://commons.wikimedia.org/w/index.php?curid=48884362*

3.4.4 Management actions

Value/issue	Threat	Implication	Actions
Helmeted Honeyeater	Gaps in understanding of relationship between hydrological regime and riparian habitat for Helmeted Honeyeaters	Inadequate or inappropriate provision of flows, impacting on the condition of this value	Melbourne Water to support/participate in further research into the impacts of hydrology on Helmeted Honeyeater habitat.
Streamside bird flow requirements	Gaps in understanding regarding the flow requirements of streamside birds in the catchment	Inadequate or inappropriate provision of flows, impacting on the condition of this value	Melbourne Water will incorporate new knowledge in to the environmental watering program and adjust flow provisions as it is identified.

3.5 Frogs

Table 7 lists frog species recorded in the VBA database for the Tarago and Bunyip system. Most of these species are common and widespread across Victoria, although there are two species with high conservation status on the list; the Southern Toadlet *(Pseudophryne semimarmorata)* and the Growling Grass Frog *(Litoria raniformis).*

Table 7 : Frog species recorded in Tarago and Bunyip catchment

Scientific Name	Common Name	FFG	Vic Advisory	EPBC
Geocrinia victoriana	Victorian Smooth Froglet			
Crinia signifera	Common Froglet			
Litoria ewingii	Southern Brown Tree Frog			
Pseudophryne semimarmorata	Southern Toadlet		Vulnerable	
Limnodynastes dumerilii	Eastern Banjo Frog			
Limnodynastes peronii	Striped Marsh Frog			
Limnodynastes dumerilii insularis	Pobblebonk Frog			
Litoria verreauxii verreauxii	Verreaux's Tree Frog			
Litoria raniformis	Growling Grass Frog	Listed	Endangered	Vulnerable
Limnodynastes tasmaniensis	Spotted Marsh Frog			
Geocrinia laevis	Southern Smooth Froglet			

Southern Toadlet populations are found near Cannibal Creek in the upper catchment, while Growling Grass Frog are typically found in the low lying areas of the lower catchment where Koo Wee Rup Swamp once was.

Most frog species require water for food, shelter and breeding habitat during their life cycles, and waterways are a critical habitat for them. The frog species known to occur in and near the Bunyip and Tarago Rivers include those that use permanent pools and other in-stream habitats, and those that use off-stream habitats such as wetlands, floodplains and damp forest.

Frogs that rely on permanent pools and other in-stream habitats include the Growling Grass Frog, the Pobblebonk, the Striped Marsh Frog, the Spotted Marsh Frog, and the Southern Brown Tree Frog. These species use permanent pools or slow flowing channel habitats with good vegetation to provide cover. They also use backwaters and anabranch channels that are filled during high flow events and hold water for long periods of time. Southern Toadlets (*Pseudophryne semimarmorata*) differ in that they are generally found in lower elevations in damp areas, in forests, woodlands, heaths and grasslands, and are not necessarily found near permanent water sources.

3.5.1 Condition and management objectives from the HWS

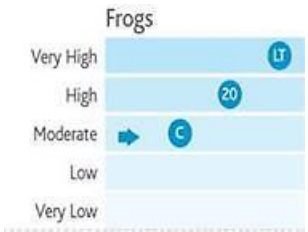
In the HWS, the condition of frogs in the Tarago/Bunyip catchments was determined by measuring species richness and then comparing species numbers recorded in surveys to the number of species expected to have occurred historically (Melbourne Water 2013). Similar to many places around the world, frog diversity has declined drastically in the past 200 years. Frog data has been collected through a number of monitoring studies and programs, including Melbourne Water's Frog Census program, DELWP programs, university assessments, and consultants.

See the Case Study below for more information on the Melbourne Water Frog Census.

A summary of condition is provided in Figure 17.

Upper Bunyip and Tarago System:

The diversity of frog populations is moderate, and has been consistent over the past decade. Works aim to improve condition to high over the next 20 years through improvements in floodplain habitat.



Lower Bunyip System:

Frog diversity is very high. Maintaining this condition over the next 20 years and beyond will be the focus of floodplain works.

Figure 17 : Condition of Frogs (Source: Adapted from Melbourne Water (2013))

Frog Citizen Science and Melbourne Water's 'Frog Census' app

Community awareness of the frog species in the Tarago and Bunyip catchments has increased significantly with the release in 2016 of Melbourne Water's 'Frog Census' app for iPhone and Android. The app has allowed for an extension of Melbourne Water's Frog Citizen Science program into West Gippsland, and a significant increase in the number of frog species has since been recorded in the region via community engagement activities. The data is informing planning and decision making on waterway health and is being added to the CSIRO's Atlas of Living Australia and the Victorian Biodiversity Atlas to share biodiversity knowledge about endangered species.

In 2016-17, sixty-five individual frog records from 31 app reports were submitted via the Frog Census app, compared to 5 individual frog records submitted (from 2 reports) in 2015-16 prior to the introduction of the app.

Species recorded by the community include:

- Eastern Common Froglet
- Victorian Smooth Froglet
- Eastern Banjo Frog
- Peron's Tree Frog
- Spotted Marsh Frog
- Southern Brown Tree Frog
- Whistling Tree Frog.

The app can be downloaded from **https://www.melbournewater.com.au/frogcensus.**

3.5.2 Key flow requirements

Some of the flow-dependent factors that can influence the distribution and abundance of frogs include:

- The availability of surface water at the right time of year - The majority of Victorian frog species mate in water and lay their eggs near, or attached to, fringing vegetation
- Surface water does not necessarily need to come from within a river channel to provide habitat and breeding areas for some species, but the connection between a river and its floodplain may be significant as overbank flows provide a source of water to wetlands and other water bodies. Overbank flood flows to floodplains can play a vital role in the long-term abundance and distribution of some frog species, with life history characteristics and behaviours that use flooding flows as a cue to move and breed when habitat is created by a flood pulse over land (Ocock *et al.* 2014)
- The ability of flows to vary salinity levels - Recent research has identified a relationship between salinity and the probability and intensity of Chytridiomycosis fungus infections in frogs (which is known to be present in South Gippsland), particularly for the Growling Grass Frog (Heard *et al.* 2014). Relatively warm and saline wetlands are environmental refuges from the fungal disease for the species and can act jointly with connectivity to sustain populations (Heard et al. 2015)
- The duration that waterways hold water (hydroperiod). For successful breeding, waterways need to hold water for long enough to allow tadpoles to develop and metamorphose into adult frogs. The duration of wetting can be as short as 6 weeks

for small, fast developing species, but for larger species it may need to be as long as a 12 months (Wassens and Maher 2011).

- The timing and velocity of flows - Still or slow flowing conditions are essential for tadpoles because high flows and fast moving water occurring at the wrong time can wash tadpoles out of suitable habitat. Tadpoles are not strong swimmers, and therefore most frog species need to breed in still, or very slow flowing water.

3.5.3 Management actions

Value/issue	Threat	Implication	Actions
Frog flow requirements	Frogs are not currently provided with flow recommendations in the catchment	Inadequate or inappropriate provision of flows, impacting on the condition of this value	Melbourne Water will continue to consult with researchers to increase knowledge and understanding of frog flow requirements and incorporate into the environmental watering program on an ongoing basis

3.6 Macroinvertebrates

Aquatic macroinvertebrates are a highly diverse group of animals found in waterways and dependent on flows from surface water or groundwater sources. The group includes insects (e.g. Mayflies, Caddisflies, and Beetles), crustacea (Yabbies and Amphipods), aquatic snails, and aquatic worms. Macroinvertebrates are an extremely important component of the Tarago-Bunyip ecosystem because they play an essential role in processing organic matter and nutrients and they are a major food source for platypus and other mammals, as well as fish, birds and frogs.

Flows are a major determinant of the abundance and composition of macroinvertebrate communities and many Australian macroinvertebrates communities have flexible life history patterns that are thought to be a direct response to highly variable and unpredictable flow regimes. For example, physical disturbance from floods and droughts is a major determinant of the spatial and temporal dynamics of macroinvertebrate communities in streams (Bunn and Arthington 2002). Macroinvertebrates are vulnerable to rapid diurnal (daily) changes in flow; and streams with erratic flow patterns are typically characterised by species-poor macroinvertebrate communities (Bunn and Arthington 2002). Available habitat, sources of food, and water quality are also major determinants of the abundance and composition of macroinvertebrate fauna.

The Tarago and Bunyip catchments support a number of macroinvertebrates with high conservation values. In particular, the area is well known for its burrowing crayfish (some of which are the only known populations in the world), and the Giant Gippsland Earthworm.

Appendix 6 provides a list of species recorded for the Tarago and Bunyip waterways.

3.6.1 Condition and management objectives from the HWS

The HWS uses SIGNAL scores (Stream Invertebrate Grade Number – Average Level) and the Australian River Assessment System (AUSRIVAS) to assess the condition of macroinvertebrates in the Tarago/Bunyip system. The two measures are combined to form an overall Index of Stream Condition (ISC) sub-index – Aquatic Life (Melbourne Water 2013). Figure 18 shows a summary of macroinvertebrate condition and the high level management objectives specified in the HWS for macroinvertebrates.

Upper Bunyip and Tarago System:

The condition of macroinvertebrate populations is high in forest reaches, with some decline in rural sections. Works to protect and improve water quality and habitat aim to raise this condition to very high in the next 20 years and beyond.

Lower Bunyip System:

Macroinvertebrate condition is moderate. Improvements in streamside vegetation and stormwater management – therefore habitat and water quality – aim to improve this condition to high within the next 20 years.

Note that earlier studies have determined the condition of macroinvertebrate communities in this area to have a very low diversity, being composed of only a handful of pollution tolerant families (EPA 1998). The moderate condition for the Bunyip Main Drain and estuary means that the macroinvertebrates probably represent the best community that can be expected in an artificial environment such as the drain, rather than as a comparison with conditions in a natural river.

Figure 18 : Condition of Macroinvertebrates (Source: Adapted from Melbourne Water (2013))

Please refer to the Case Study below for more information about one of these burrowing crayfish, the Warragul Burrowing Crayfish.

Warragul Burrowing Crayfish

West Gippsland is home to the only known population of a small, pale coloured burrowing crayfish called the Warragul Burrowing Crayfish (*Engaeus sternalis*). It is thought to be one of the rarest species of burrowing crayfish in Australia, inhabiting a small area (approximately 16 km^2) of riparian habitat near Labertouche Creek and the Tarago River (Doran and Horwitz 2010, Van Praagh 2016).

The Warragul Burrowing Crayfish belongs to a group of crayfish called terrestrial or land crayfish, which rarely inhabit open waters. Very little is known about the species, but it is thought to live most of its life in an underground burrow system, coming to the surface at night to seek mates in spring and summer or after heavy rains. It is thought to dig its burrows down to the water table but may also reside in smaller chambers filled with mud that are closer to the surface.

The burrows of Australian crayfish can be classified into the three categories:

1. Burrows in, or connected to, open water
2. Burrows connected to the water-table
3. Burrows independent of the watertable.

Warragul Burrowing Crayfish are thought to belong to the second category (Doran and Horwitz 2010, Van Praagh 2016).

The full extent that the Warragul Burrowing Crayfish relies on water availability is not currently known. What is known is that burrowing crayfish species which rely solely on catchment flows and overbank flows to floodplains are found only in Australia, and they have so far all been *Engaeus* species. The species is thought to be particularly vulnerable to changes in groundwater availability, through loss of overbanks flows and through water regulation.

An assessment of the vulnerability of Warragul Burrowing Crayfish to climate change is provided in Section 13.2.3.

3.6.2 Key flow requirements

Very little is known about the specific flow requirements of individual groups or species of macroinvertebrates. Changes to the natural pattern of flows for a river are likely to cause changes in the biodiversity of macroinvertebrate communities however. Walsh *et al.* (2011) have found that lower than normal flow in the two years prior to a sampling event can be a strong predictor of poor macroinvertebrate condition in a waterway. This finding suggests that when rivers are flow stressed, such as during drought or regulation, the condition of the macroinvertebrate communities in those rivers can decline. It is thought the macroinvertebrate communities are responding more to a general decline in the quality and quantity of available wetted habitat than to specific flow components.

Key flow-dependent factors that can influence macroinvertebrate condition include the availability of adequate flows for habitat, and the indirect effects of flows on physical habitat and/or water quality, such as salinity and temperature.

3.6.3 Management actions

Value/issue	Threat	Implication	Actions
Warragul Burrowing Crayfish flow requirements	Climate change and land use change may impact water availability and habitat for Warragul Burrowing Crayfish species, by reducing water table and/or wetted sub-surface habitat	Possible loss of habitat extent and/or quality for threatened species such as Warragul Burrowing Crayfish through inadequate flows provision	• Melbourne Water will undertake research to better understand dependence of the Warragul Burrowing Crayfish on surface water and groundwater flows • Work to understand the connectivity and protection of groundwater/surface water in Labertouche Creek

3.7 Amenity

Amenity is the pleasantness, attractiveness, or agreeable nature of a place. The HWS defines amenity as "the pleasantness of a waterway to visitors and the ability of the waterway to provide a restorative escape from the urban landscape" (Melbourne Water 2013). The value forms part of a larger set of attributes associated with the social and natural aspects of waterways.

Some of these attributes include experiential values, such as:

- Connecting with nature and/or community connectedness
- Passive and active recreation
- Using waterway corridors for transport (biking, running, boating)
- Learning from the environment
- Engaging with an aesthetically pleasing space
- Engaging with art and culture.

Waterways also provide corridor values, such as:

- Providing cool environments, helping to mitigate the urban heat island effect
- Natural vegetation connecting different habitats.

The amenity values associated with the Tarago and Bunyip Rivers are intrinsically linked to the quality and extent of their natural vistas, the green spaces they provide, the vegetation, and the natural surroundings. Physical aspects such as the sight and sound of running water, accessibility to the area, the ability to move along or around the waterway and the facilities that enable time to be spent beside the river are also very important for people.

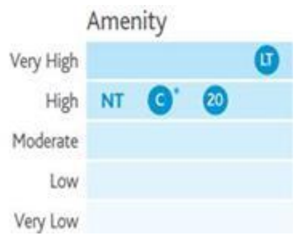
Amenity means different things to different people, but is the most commonly expressed reason for visiting waterways by the community, and is an important value that needs to be managed and protected (Melbourne Water 2013). Amenity values are currently being reviewed as part of Melbourne Water's Healthy Waterways Strategy review, and future reviews of the EWMP will incorporate this information when available.

3.7.1 Condition

It is challenging to measure the condition of amenity for waterways. In putting together the 2013 HWS, a tailored social research program survey was used by Melbourne Water to assess how the community values and relates to waterways in the region.

Upper Bunyip and Tarago System:

High amenity values are still provided and reserved through natural forests, picnic areas along rivers and streams and vistas along waterway corridors.



Lower Bunyip System:

Some waterways have been dramatically altered and amenity is low. Actions targeted at improving vegetation will increase the condition to moderate in the long term, but the small amount of public land and limited access to waterways will restrict the overall gain possible.

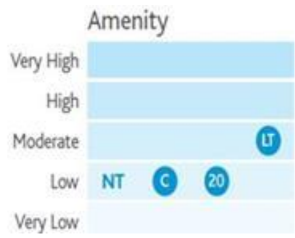


Figure 19 : Condition of Amenity (Source: Adapted from Melbourne Water (2013))

3.7.2 Key flow requirements

The flow requirements of amenity values are challenging to define and Melbourne Water is working to improve the sub-measures that make up these social, cultural and economic values for the next iteration of the HWS, which is due for release in 2018.

Melbourne Water is also working to incorporate additional measures of waterway condition that better capture amenity values, and this requires an analysis of social and cultural values so that their benefits are better understood and articulated. In the future, it will be important to incorporate amenity values for consideration as part of flows study reviews for the system, in recognition of the important role these values play in community health indexes.

3.7.3 Management actions

Value/issue	Threat	Implication	Actions
Amenity values	The flow requirements of amenity values are	Inadequate or inappropriate provision of flows, impacting on	• Melbourne Water is working to improve the sub-measures for amenity

Value/issue	Threat	Implication	Actions
	poorly understood and difficult to measure in terms of condition changes	the condition of these values for communities	• Where possible, flow provisions for amenity values will be incorporated for management over time
Community engagement and advocacy	Poor and/or decreasing community engagement and understanding of waterway values	May decrease the 'social licence' of Melbourne Water and VEWH to provide environmental flows, particularly during times of drought and/or climate change impacts	• Melbourne Water will continue to deliver and support community engagement, education and awareness raising activities, as they are critical to maintain social licence for the environmental watering program • Melbourne Water will explore the feasibility of delivering a range of innovative social media and citizen science programs focused on the Tarago-Bunyip system to facilitate this engagement

3.8 Aboriginal cultural values

People have lived and prospered in south-eastern Victoria for at least 30,000 to 40,000 years (Presland 2001), and the physical evidence of this occupation is present almost everywhere. Sub-surface archaeological deposits, shell middens, quarries, eel traps, artefacts scatters, scarred trees and oven mounds bear witness to many generations of continuous use by people prior to the arrival of Europeans. This enormous span of time prior to the occupation by Europeans is often a missing element in narratives about Australia (Presland 2001), and the water-dependent Aboriginal values of waterways are also only just beginning to be documented and incorporated into management plans in this country (Finn and Jackson 2011).

The Tarago and Bunyip Rivers traverse land associated with the Woi wurrung people (now often referred to as the Wurundjeri) and the Bun wurrung people (also called Boon wurrung and Bunurong) (Clark 1990, p 364, Presland 1994, Eidelson 1997) (Figure 20). The Gunai Kurnai people of Gippsland may also have a strong connection to Country of the Tarago and Bunyip catchments.

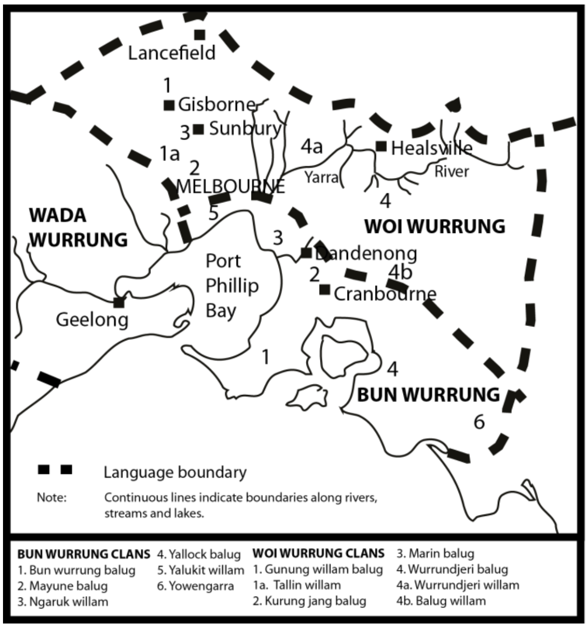


Figure 20 : Aboriginal language group boundaries of the Greater Melbourne area (after Clark 1990)

Today, the Woi wurrung are represented by the Wurundjeri Tribe Land Compensation and Cultural Heritage Council Incorporated (WTLCCHC), the Bun wurrung by the Bunurong Land Council Aboriginal Corporation (BLCAC) and the Boon Wurrung Foundation Ltd (BWF), and the Gunai Kurnai are represented by the Gunaikurnai Land and Waters Aboriginal Corporation (GLaWAC). All three groups have previously submitted applications to have Representative Aboriginal Party (RAP) status for areas that include parts of the Tarago and Bunyip system, although none of these applications have been granted to date (DPC 2017).

The headwaters of the Tarago and Bunyip Rivers are generally thought to be within Woi wurrung country. According to Clark (1996), the clan most likely to be associated with the upper reaches of the Tarago and Bunyip Rivers is the Bulug willam (see Figure 20). Their Country is described as the ranges and swamps of the Upper Yarra, south-east to Koo Wee Rup Swamp and south-west to Cranbourne. The mouth of the Bunyip River is thought to be within Bunurong Country. The clan likely to be associated with this area is the Yallock balug (Clark 1996). The Brataualung people of the Gunai Kurnai may have used parts of the Bunyip and Tarago catchments, as they were known to inhabit South Gippsland.

3.8.1 Water-Dependent Cultural Values

For many Aboriginal people, their spirituality derives from a philosophy that encapsulates a wholistic notion of the interconnectedness of the elements of the earth and the universe, animate and inanimate, where people, plants and animals, landforms and celestial bodies are all interrelated (Grieves 2009). In this world view, rivers are seen as an important spiritual and cultural value, often derived from the actions of mythic beings during the Dreaming.

Due to the need for a separate and culturally sensitive consultation process, extensive consultation with Aboriginal Traditional Owners was not possible during the development of the EWMP. Based on a search of literature that is publicly available, a number of possible water-dependent cultural values have been identified for the Tarago and Bunyip Rivers however, and these are summarised below.

Animals

Aboriginal people lived off a wide variety of animal resources before European contact. The following fish species were likely to have been hunted and eaten by the Aboriginal people of the area:

- River Blackfish
- Eels ('Iuk' in Woi wurrung)
- Lamprey
- Southern Pygmy Perch
- Tupong.

Fishing remains a popular activity for many Aboriginal people, and key species could include River Blackfish, Tupong and Eel. Crayfish and turtles may have also been sourced from the rivers.

Small game found in the riparian and floodplain areas, such as Southern Brown Bandicoots, possums, water-rats, lizards and birds were also likely to have been important components of the diet (Sullivan 1981). For coastal people, seafood such as mussels and oysters could have been collected from the saltmarsh and mangrove habitats of the Estuary and Western Port. In the mangroves, people may also have harvested mangrove crabs.

Plants

The riparian and aquatic environment would have provided staple plant food sources such as rhizomes and tubers, as well as valuable fibre sources for weaving and twine (Gott and Conran 1991). Table 8 provides a summary of a range of plant species located within the aquatic, riparian and floodplain areas of the Tarago and Bunyip Rivers that may have been used by Aboriginal people.

Table 8 : Plant species potentially used by Aboriginal people in the Tarago and Bunyip waterway corridors (Source: http://melbournewalks.com.au/aboriginal-food-plants)

Species	Uses
Common Reed (*Phragmites australis*)	A multipurpose plant. The shafts were used in the manufacture of spears and the leaves woven into baskets. Sections of the hollow stems were strung into reed necklaces or used as nose ornaments. In Gippsland, the sharpened ends of the stems are made into knife-like instruments for skinning animals. The roots can also be eaten.
Water Ribbons (*Triglochin procerum*)	The sweet underground tubers were an important food source, and were collected and eaten raw.
Cumbungi or Bull-rush (*Typha orientalis)*	A staple food source for indigenous people throughout South-Eastern Australia. The floury rhizomes were steamed in earth ovens or roasted in fires, the edible portions consumed and the tough fibres that remained were scraped with mussel shells and made into twine.
Manna Gum (*Eucalyptus viminalis*)	Bark was harvested from a variety of tree species to make water containers, shields, lean-to shelters, and canoes. Manna Gum, often found within riparian areas, was potentially used for this purpose.
Swamp Paperbark (*Melaleuca ericifolia*)	The tree has whitish papery bark that peels off in strips. Aborigines used the bark from mature trees for rugs, bandaging and thatching for their housing. Oil from the leaves was used to treat coughs and colds, and the stems were used for spears and digging sticks.
Yam Daisy (Murnong) (*Microseris scapigera)*	The tubers of the Murnong were probably the most relied-upon staple food for the Aborigines of Victoria. When cooked in rush baskets in ground ovens overnight, they produce a sweet syrup

Species	Uses
	and are very good to eat. Yam Daisy was a cultivated food source, demonstrating that Australian Aboriginal people relied on farming practices to ensure a constant food supply, contrary to the still predominant belief that they were a predominantly hunter-gatherer society.
Mint *(Mentha spp.)*	Leaves were crushed in the hands and the vapour inhaled for colds and coughs. Also used to abate stomach cramps, and as a food flavouring.
Bulbine Lily *(Bulbine bulbosa)*	The tubers of the Bulbine Lily are one of the sweetest lily roots and were eaten all year round
Kangaroo Apple *(Solanum aviculare)*	The fruits of many species of Kangaroo Apple were an important food for Aboriginal people, but were only eaten when they were completely ripe, as were otherwise highly poisonous. The fruit would sometimes be placed in sand to ripen before being eaten.
Blackwood (*Acacia melanoxylon*)	The fibre of this tree was used to make fishing lines while its timber provided weapons such as woomera, shields and throwing-sticks. It also has medicinal uses: an infusion of its bark can be used to treat rheumatic joints.

The water-dependent values of the Tarago and Bunyip Rivers are not well documented, and where Aboriginal people have indicated it is culturally appropriate to do so, Melbourne Water will collaborate and consult with the Traditional Owners of the Tarago/Bunyip catchments to document and incorporate these values into management strategies for the waterways.

Intangible values

Water-dependent Aboriginal cultural values do not end at collections of objects, plants or animals. They also include traditions or living expressions passed from generation to generation, such as stories about the waterways, performing arts, social practices, rituals, festive events, knowledge and practices concerning nature and the universe, or the knowledge and skills to produce traditional crafts. Significantly, for the first time in Australia, Victorian legislation now provides for the explicit protection of intangible Aboriginal cultural heritage values, such as stories, song and language, through updates to the Aboriginal Heritage Act in 2016.

Where Aboriginal people have indicated it is culturally appropriate to do so, Melbourne Water will collaborate with the Traditional Owners of the Tarago/Bunyip catchments to document and incorporate these values into management strategies for the waterways.

3.8.2 Condition of water-dependent values

European occupation of the Greater Melbourne region led to the severe disruption of Aboriginal traditional life and whole populations were decimated through disease, dispossession from Country, or through violent conflict (Finnigan 2001). For this reason, little information survives regarding the lives of those living in the Tarago and Bunyip catchments before European contact. Despite these impacts, there is still a high potential for water-dependent Aboriginal cultural values to remain; tangible and intangible, traditional and contemporary.

It will be important to identify and document these values for the Tarago and Bunyip Rivers, so that Aboriginal people are able to preserve this knowledge and pass on to the younger generation, as well as to improve the opportunities for collaborative management of the waterways. Where culturally appropriate, Melbourne Water will collaborate with Traditional Owners to assist in this task.

3.8.3 Key flow requirements

Although the records are incomplete, the people of the Kulin Nation have documented seven different seasons:

- Iuk - Eel Season (March)
- Waring - Wombat Season (April to July)
- Guling - Orchid Season (August)
- Poorneet - Tadpole Season (September to October)
- Buath Gurru - Grass Flowering Season (November)
- Kangaroo-apple Season (December)
- Biderap Dry Season (January to February) (Museum of Victoria 2017).

The ability to link events in the natural world to a cycle that predicts seasonal changes is a key factor in the successful development and implementation of environmental watering programs because these natural barometers are not uniform across the land, instead using the reaction of plants and animals to gauge what is happening in the environment. In future reviews of the Tarago and Bunyip Rivers FLOWS study, Melbourne Water will also investigate the feasibility of incorporating traditional seasons into the flow recommendations, and will work closely with Traditional Owners to determine how to appropriately incorporate this knowledge. Melbourne Water will also investigate the feasibility of tailoring its seasonal environmental watering strategies for the Tarago and Bunyip to be more aligned with this seasonal understanding.

3.8.4 Management actions

Particularly where rivers are flow stressed, there is a tendency to focus on key places or sacred sites as Aboriginal people strive to reinstate or retain their traditions. However, affiliations to water are much broader than those encompassed by a conventional cultural heritage point of view, encompassing humanitarian values relating to notions of sociality, sacredness, identity and life-giving (Jackson 2015). As a consequence, it is important to not assume that environmental flows and/or seasonal changes can be used as a direct surrogate for meeting Aboriginal social, cultural or spiritual requirements.

For this reason, a more rigorous assessment of these tangible and intangible values will be important to complete via a specially designed cultural values flows study, the findings of which will be incorporated into Melbourne Water's Seasonal Watering Proposals for the Tarago and Bunyip systems.

Management actions, delivered over the next 2 to 5 years, are summarised below.

Value/issue	Threat	Implication	Opportunities
Water-dependent cultural values	The flow requirements of water-dependent cultural values are poorly understood and not yet well integrated into water management programs	• Inadequate or inappropriate provision of flows could impact on the condition and continuity of these values • Impacts on Aboriginal community health and wellbeing	• Melbourne Water will work with Traditional Owner groups to identify and document water-dependent values and their flow requirements and incorporate into the environmental watering program on an ongoing basis • Melbourne Water will also document and incorporate water-dependent values into its broader waterways management strategies where culturally appropriate, such as the Healthy Waterways Strategy

Engaging with Traditional Owners to identify and protect water-dependent cultural values presents important opportunities for Melbourne Water and the broader community to move the management of the Tarago-Bunyip system towards a more inclusive, diverse and enriched partnership program. The opportunities for continued capacity building between Melbourne Water, Traditional Owners and the community are very positive, and the intersection of western ecological knowledge and traditional ecological knowledge and connection to Country is likely to strengthen the management of the environmental watering program for better outcomes.

3.9 Overall stream condition (ISC)

Waterway condition for the Tarago and Bunyip Rivers has been assessed using Victoria’s five-yearly Index of Stream Condition (ISC) process, which provides an overall measure of the relative environmental condition of rivers when compared to reference condition. The ISC combines information on hydrology, water quality, physical form, vegetation, and aquatic life, and provides an overall basin condition assessment as well as reach specific assessments. Using data collected between 2004 and 2010, the most recent ISC assessment found that most reaches along the Tarago and Bunyip Rivers were in moderate condition, with one reach (Bunyip Estuary) in very poor condition (Figure 21).

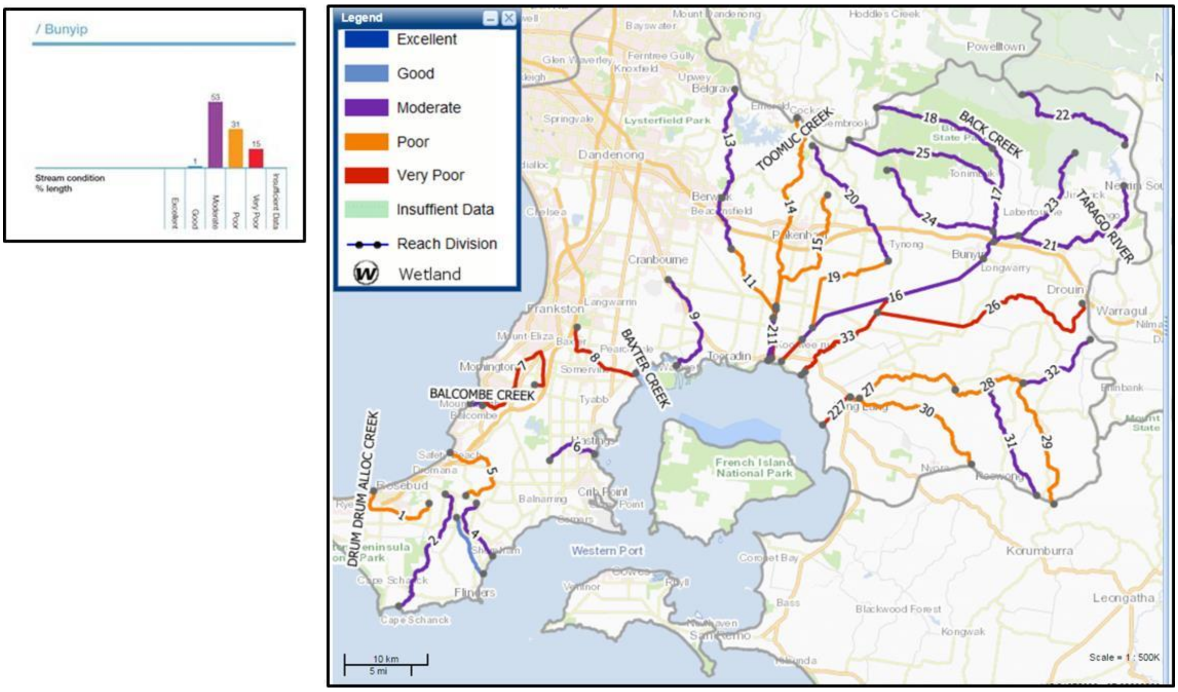


Figure 21 : Index of Stream Condition map for the Bunyip Basin showing condition ratings (Source: Index of Condition System (State Government of Victoria 2017))

Table 9 shows the 2010 scores for the range of sub-indexes assessed for the ISC, where 0 equals very poor and 10 equals excellent. The approximate correspondence with environmental flows study reaches is also indicated in the table.

Table 9 : Index of Stream Conditions scores for Tarago and Bunyip waterways (Source: State Government of Victoria (2017))

ISC Sampling Point	Location and approximate reach	Hydrology	Streamside Zone	Physical Form	Water Quality	Aquatic Life	ISC Score	Condition
16	Bunyip Main Drain (Reach 6)	8	7	4	8		31	Moderate
17	Back Creek (reach not included)	8	5	7	3		25	Moderate
18	Back Creek (reach not included)	4	7	9		9	32	Moderate
21	Tarago River (Reach 2)	8	6	6	6	9	32	Moderate
22	Tarago River (Reach 1)	8	7	10	1	10	29	Moderate
23	Labertouche Creek (Reach 3)	8	7	7	4	6	29	Moderate
24	Cannibal Creek (Reach 4)	4	10	7			31	Moderate
25	Diamond Creek (reach not included)	5	7	9	3	8	27	Moderate
216	Bunyip Main Drain (Reach 7)	2	10	5	3		19	Very Poor

4 Threats

A range of key threats to water-dependent values of the Tarago and Bunyip Rivers are summarised in Appendix 5. These threats were identified by stakeholders consulted during the development of the EWMP, the FLOWS studies, as well as reviews of relevant literature.

A number of emerging threats are discussed in greater detail in Sections 4.1 to 4.3 below, while two key threats - changed hydrology and climate change - have separate analyses in the EWMP (Section 6 and Section 13).

4.1 Land use change

Land use change represents a significant threat to the Tarago and Bunyip Rivers, but also strong opportunities for tailoring management responses. Key land use change includes urbanisation, agricultural intensification (e.g. conversion from grazing to cropping or horticulture), and subdivision for rural life-style. Land use in the Tarago and Bunyip Rivers area is becoming more diverse because:

- Farming in the area is changing and expanding in response to changing consumption patterns and the need to remain profitable and sustainable. Farming enterprises are also intensifying, such as aquaculture, poultry farms and horticulture, and are growing in numbers in the region. An expansion of irrigation in the area is also possible, with communities and business keen to protect and support the growth of the Bunyip Food Belt as a key food producing area for metropolitan Melbourne and Victoria (McKinna et al. 2013)
- At the same time, people are moving in ever increasing numbers from Melbourne, and also from the urban centres of the region to the less developed rural areas. This is particularly felt around the main centres, along the Gippsland rail corridor and in higher amenity areas to the north toward Neerim (Hansen Partnership 2016). The rural landscape features add residential value to many of the rural localities within the area, with this resulting in an increased number of individuals choosing to move for lifestyle reasons.

4.1.1 Intensification of agricultural practices

An intensification of agricultural enterprises is a projected trend for the future of the region, as other areas of Victoria become less productive due to climate change and/or changing international and national markets alter what is most economic to produce in the region (Hansen Partnership 2016). This applies to traditional animal industries such as grazing and dairying operations, and to horticultural practices through the increasing use of hot houses and hydroponics. The trends towards intensification are likely to significantly change the volume and patterns for demand of water in the region.

Recent local government publications have stressed the importance of planning controls to maximise the productive use of agricultural land in the area as well as minimise the unplanned and/or incremental impacts to the social, environmental and economic values of the region (Hansen Partnership 2016). However the potential effects of land use change on water availability and flow regimes are not yet well defined or understood. The establishment of new land uses does not always involve water authorities because dams for stock and domestic purposes do not trigger any requirements if they are not on waterways, nor does access to water in waterways on a property or the use of a bore for the same purpose (noting that a licence is required for construction).

For these reasons, it will be important for Melbourne Water to facilitate and/or participate in regional strategic growth planning and consultation processes, to better understand and predict the extent of land use change in the catchment and its impacts on water resources, streamflow and the flow regime. It will also allow Melbourne Water and partners to determine when an increase in water use becomes significant and requires more intensive management – for example by causing unacceptable impacts on the environment.

4.1.2 Increasing demands for water

Increasing urban development and population growth in the mid reaches of the Tarago and Bunyip catchment is of concern because of its potential to increase the volume and velocity of poor water quality stormwater inputs into the Bunyip River, the additional demands this growth places on consumptive water sources, and the increasing number of farm dams capturing catchment runoff on peri-urban properties.

With increasing population numbers comes increasing demands for drinking water. At Perderson Weir on the Tarago River for example, extractions to supply water to Warragul may increase to the point that inflows to Tarago Reservoir are decreased. As diversion demands increase, there is likely to be less above cap water available downstream of the weir to augment the passing flows. Inflows to Tarago Reservoir are impacted during times of low flow and/or increasing demand, and as a consequence, the accumulation of the 10.3% share of inflows for the Environmental Entitlement may be vulnerable. This threat remains uncertain, and Melbourne Water will work with key delivery partners to better understand its likelihood and consequences for the Environmental Entitlement. This issue is discussed further in Section 15.1.1.

4.1.3 Stormwater

The local government areas of Cardinia and Baw Baw Shire are some of Victoria’s fastest growing municipalities. Modelling has predicted that the population of Baw Baw Shire is expected to almost double by 2036 to more than 76,000 people, and Cardinia Shire to also almost double to approximately 180,500 people (Cardinia Shire Council and Alluvium 2015, Baw Baw Shire Council 2017). In Cardinia Shire, the number of dwellings in the shire is likely to increase by an average of 1,575 dwellings per year, up to 69,213 in 2036, with an area of approximately 4,000 hectares extra planned for this development (Cardinia Shire Council and Alluvium 2015).

Urban development presents a threat to the rivers and streams in the Bunyip and Tarago catchment because of additional changes to their already impacted flow regimes and reductions in water quality. However, the areas set aside for urban development are relatively small compared to the total catchment area, so the impacts are likely to be localised and most strongly felt in small tributary streams where a larger proportion of the catchment could be developed (e.g. Garfield and Bunyip (Cardinia Shire) and Drouin (Baw Baw Shire).

In those areas that do experience urban development, flow regimes can be altered by increases in catchment imperviousness, reducing the infiltration of rainfall into the soil, decreasing recharge to groundwater and increasing the rate of surface water runoff. This increased surface water runoff is collected in stormwater drainage systems and is then discharged into receiving waterways. This alteration of infiltration and runoff regimes ultimately results in an overabundance of flow, through increases in the volume and velocity of water entering the rivers as well as increases in the frequency of high flows they experience (Duncan *et al.* 2014). This can increase erosion within and along the waterways, which drives a further deterioration in water quality because sediment, nutrients and other contaminants that would otherwise have been held and recycled in the catchment now enter the waterways (Walsh *et al.* 2005, Walsh *et al.* 2012).

It is estimated that by 2031, Cardinia Shire will experience an additional 25 GL per year of stormwater within an average year as a result of this urbanisation, although not all of this will be generated in the Bunyip catchment (the majority being generated in catchments to the east such as Cardinia Creek and Toomuc Creek) (Figure 22).

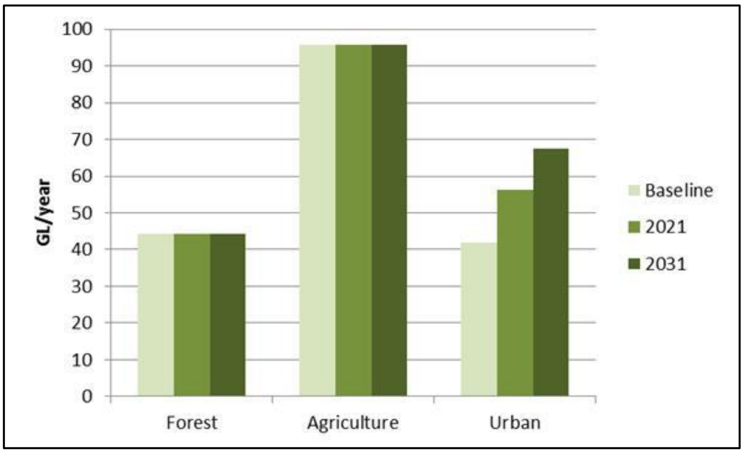


Figure 22 : Projected stormwater volumes by land use source, Cardinia Shire (Source: (Cardinia Shire Council and Alluvium 2015))

Table 10 summarises the likely threats to the values of the Tarago and Bunyip Rivers as a result of land use change.

Table 10 : Threats to habitat and ecological values as a result of land use change

Value	Threat
Habitat Values (i.e. amount and quality of habitat)	
Water Quality	• Increased freshwater flows may dilute naturally occurring salinity, particularly within the estuarine environment and receiving waters of Western Port. • Changes in base flow may decrease nutrient retention and assimilation at the reach scale and increase the export of nutrients to downstream reaches, including the Bunyip River estuary and Western Port. • Agricultural intensification can lead to increased nutrient and sediment loads in runoff to receiving waters.
Stream Geomorphology	• Urbanised headwaters are highly prone to channel incision (headcuts and channel widening). • Some scouring of bars and benches is also likely. • Removal of substrate gravels is also likely in the lower reaches, as is scouring of the floodplain.
Ecological Values	
Fish	• Increased frequency of high flows may scour vegetation from pools and reduce pool habitat quality for fish, for example River Blackfish. The increased frequency of high flows as a result of urbanisation generally has a negative impact on all native fish because these flows can cause direct mortality and displacement of eggs and juveniles, remove key physical habitat (e.g. woody debris, undercut banks, rocks, aquatic vegetation), and render large sections of channel unsuitable due to elevated flow velocities.
Frogs	• Increased frequency of high flows may scour vegetation from pools, hence reducing quality of habitat, particularly for Growling Grass Frog. • Increased frequency of high flows may flush tadpoles from nursery habitats, hence reducing recruitment success. Increased freshwater flows may also reduce naturally elevated salinity and hence reduce buffering capacity against Chytrid fungus. However, permanent low flows may help extend the range of some frogs into some areas.

Value	Threat
Macroinvertebrates	• Introduction of a more permanent flow regime may result in a shift in species diversity and richness, with a loss of species adapted to ephemeral flows and an increase in species that prefer permanent flowing conditions.
Vegetation	• Increased frequency of high flows may scour pools and reduce opportunities for submerged macrophytes to persist. • Increased frequency of high flows may result in changes to vegetation zonation in the littoral zone.

Estimates from other catchments in the Greater Melbourne region indicate that stormwater may need to be contained by as much as 90% to maintain current flow regimes within developing catchments (Burns *et al.* 2013, Duncan *et al.* 2014). A carefully designed regional stormwater harvesting scheme will have the greatest potential to fill this gap – noting that no solution will completely mirror the complexity of nature.

4.1.4 Management actions

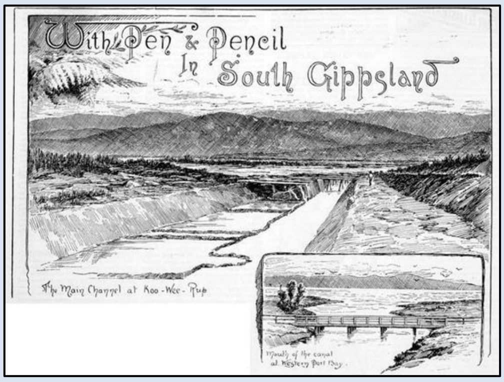
Value/issue	Threat	Implication	Actions
Urban development and population growth	• Increasing DCI and associated stormwater impacts in the mid reaches • Increasing urban water demands and extraction from Pederson Weir	• Poor habitat quality and direct impacts on species and communities will impact on Melbourne Water's ability to protect and/or improve condition of water-dependent values • Accumulation of the Environmental Entitlement volume may be considerably slowed down, impeding the ability to provide appropriate flow volumes	• Melbourne Water will continue to work with key delivery partners to develop and deliver appropriate stormwater management strategies that help to protect flow regimes. • Melbourne Water will work with key delivery partners to understand the likelihood and consequences of increasing demands for extraction at Pederson weir.
Agricultural intensification	• Conversion from grazing to cropping and horticulture. • Proliferation of farm dams	• Increased sediment and nutrient loads in runoff from disturbed areas. • Retention of rainfall and impacts on low flows	• Melbourne Water will work with key delivery partners to understand the impacts of agricultural intensification on flow regimes and values in the catchment

4.2 Drainage of Koo Wee Rup Swamp

Koo Wee Rup Swamp was for many years viewed by European settlers as an inconvenience for travel, an ugly waste of land, and a flood risk. While attitudes towards wetlands have now considerably changed, the consequences of this viewpoint have created ongoing threats for the lower catchment, including sedimentation and flooding.

Early European perspectives on Koo Wee Rup Swamp

Koo Wee Rup Swamp was described in 1883 by a reporter for the newspaper 'The Argus', capturing an early European perspective of the Swamp:



"This great supply of water, which, owing to the excessive rainfall of the Gippsland district, is considerably augmented in the winter months, was thus poured for acres over the level country, with the effect of converting it into a piece of trackless swamp land. There is a dismal uniformity in the appearance of the land, sufficiently depressing to have deterred the earlier settlers from exploring any great portion of it. The ti tree, indigenous to Australian marsh lands, grows so thickly over the whole face of it that the twisted trunks are jammed together like corn stalks in a wheat field. The western part has to some extent been reclaimed by the settlers, but the Crown lands on the east, forming a tract of some 50,000 acres, still receive the waters of the Tarwin and Bunyip rivers, and are only inhabited by flocks of marsh birds and small herds of Sambar deer, which feed on the yellow weed and other marsh plants, and retire to occasional elevated sand hummocks for shelter…..

At present the only means of carriage for settlers on the southern side are large boats, which are run up these inlets and floated out with the succeeding tide." (The Argus 1883)

Image source: The Illustrated Australian News, January 1st, 1892 (http://trove.nla.gov.au/newspaper/article/60443420/5975093)

4.2.1 Erosion and sedimentation

Koo Wee Rup Swamp contained variable thicknesses of peat and clay, which acted as a natural sponge for absorbing water. After drainage of the Swamp started, these areas of peat and clay weren't able to perform their usual absorption behaviours and high velocity water was now flowing down newly constructed and unstable drains. This high velocity water still causes significant erosion problems in the lower catchment. As early as 1916 it was recorded that erosion deposits from the Bunyip Main Drain were leaving a thick and long layer of sediment going out to sea at Western Port, and layers of sand nearly two metres thick were building up in the Bunyip and Lang Lang Rivers (Wallbrink and Hancock 2003).

Erosion remains a significant issue for Bunyip River. The deepening of the river bed for drainage has caused a headward erosion[12], which has increased the inputs of downstream sediment (Wallbrink and Hancock 2003). Sedimentation issues linked to catchment erosion concerns are thought to have caused the major decline in seagrass beds in Western Port between 1970 and 1984 (Jenkins et al. 1997). These losses were paralleled by a 40% decline in the total commercial catch of finfish in the bay (Drew *et al.* 2008).

4.2.2 Flooding

The area once covered by Koo Wee Rup Swamp is located in a basin shaped area of low lying land, which means that even with its extensive drainage infrastructure, it is still susceptible to flooding on a regular basis, and is considered one of the most flood prone areas in Victoria. Several major floods have occurred in the past century, including a flood in 1934 that left 1000 people homeless. Part of a designated flood protection area, the Koo Wee Rup – Longwarry Flood Protection District, regular maintenance of drainage structures is undertaken by Melbourne Water to reduce the risk of flood

[12] Headward erosion is the process by which a river erodes its source region, lengthening its channel in a direction opposite to that of flow.

impacts in the District. These activities include de-silting, vegetation control, erosion control, bridge and levees maintenance, debris removal and repairs.

Protecting conservation values such as the Australian Grayling, Southern Brown Bandicoot and platypus while also maintaining flood protection along the Bunyip Main Drain can create complex management issues, with some stakeholders seeing the main value of the district's drains as providing drainage, and others viewing the conservation values of prime importance.

4.2.3 Management actions

Value/issue	Threat	Implication	Actions
Management of Koo Wee Rup area for flood mitigation	Ongoing erosion and sedimentation issues	Poor water quality and consequent impacts to habitat within Bunyip River and the receiving waters of Western Port	Melbourne Water will continue to consult and work with key delivery partners to improve understanding of the link between ongoing drainage of Koo Wee Rup area and sedimentation impacts in Western Port.

4.3 Deer

Deer are among the world's most successful invasive mammals and can have substantial negative impacts on natural and agricultural ecosystems. Six species have established wild populations in Australia, and the distribution and abundances of some species are increasing (Davis *et al.* 2016). During the development of the EWMP, stakeholders noted that deer are very prevalent in the upper catchment and are causing considerable damage to riparian vegetation as well as farmland in the area. The type and severity of impacts and the mechanisms involved are diverse for feral deer, ranging from the direct physical impacts of foraging on native flora and crops, through to indirect impacts on native fauna and livestock from competition and disease transmission, and complex changes to ecosystem interactions (such as nutrient cycling) (Davis *et al.* 2016). In Australia, establishment of wild deer populations began in the mid-1800s, when Acclimatisation Societies released species such as Sambar (*Cervus unicolor*) for hunting (Figure 23). In Victoria, deer are protected from hunting and are accorded protection equivalent to that for native animals; while in other states they are a declared pest species.

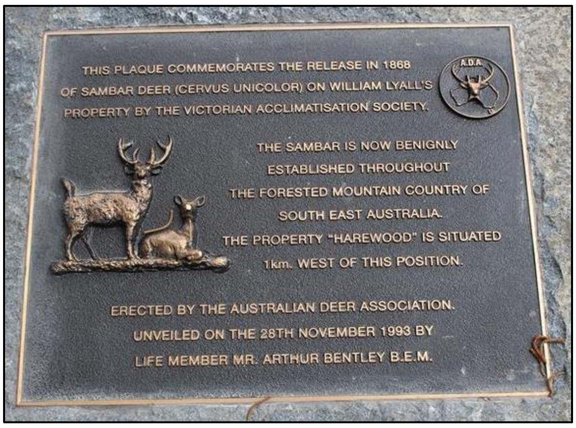


Figure 23 : Plaque commemorating the release of Sambar Deer into the lower Bunyip catchment, located at the Koo Wee Rup viewing platform.

4.3.1 Management actions

Value/issue	Threat	Implication	Actions
Deer	Direct impacts on vegetation, catchments and species/communities	Poor quality and availability of habitat for native species and communities, decreasing their population abundance and distribution	While this threat cannot be managed or mitigated by environmental flows, Melbourne Water will work with key delivery partners to increase understanding of the extent of the problem and possible management actions.

Chapter 3 - Hydrology

The majority of the Tarago/Bunyip system is highly regulated, with weirs and impoundments defining the timing, volume and duration of a significant proportion of flows. This regulation has had a significant impact on the hydrology of the Tarago and Bunyip Rivers, and represents a key threat for their water-dependent values.

5 River regulation

Water is harvested from a number of points along both the Tarago and Bunyip Rivers via dams, weirs and direct extraction. The largest dam is the Tarago Reservoir at Neerim South, which is connected to the Melbourne system and also supplies Westernport and the Mornington Peninsula (Melbourne Water 2016). Other structures include Pederson Weir, which is located on the Tarago River upstream of Tarago Reservoir, and Bunyip Diversion Weir, which is just upstream of the confluence of the Tarago and Bunyip Rivers.

Water from the Tarago-Bunyip system is used for a range of purposes including for consumptive supply (following treatment from Tarago Reservoir) to Melbourne, parts of Gippsland, the Mornington Peninsula and Westernport, direct extraction for irrigation and to support the ecological values of the system.

The rights to consumptive water in the system are described in the *Bulk Entitlement (Tarago and Bunyip Rivers – Melbourne Water) Order 2014,* which caps extraction from the system to an annual average of approximately 30,510 ML (24,950 ML at Tarago Reservoir and 5,560 ML at the Bunyip Weir) over any consecutive 5 year period.

Appendix 1 describes the water rights arrangements for the Tarago-Bunyip system.

6 The impacts of regulation on hydrology

As a result of regulation, hydrological regime of the Bunyip-Tarago River system has changed considerably from what would have been the natural flow patterns. The alterations began with the efforts to drain the Koo Wee Rup Swamp in the second half of the 19th century. The Bunyip Main Drain was completed in 1893, which opened the area up to agricultural development, and by 1904, more than 200 people lived on the area of the former swamp (Arnold 2012). The next major alteration to the hydrology of the system was the construction of the Tarago Reservoir, which was completed in 1968. The smaller weirs on the system and direct extraction have also impacted the hydrology of the system.

The hydrology of the upper reaches, which are unregulated and flow through forested catchments, has been essentially unchanged from natural. However, in the lower reaches, the mean annual flow is significantly reduced from natural (for most impacted reaches in the order of 10 – 20%). There have also been changes to the frequency of event driven flow in some reaches (smaller flows are more common and larger flows are less common). Despite the reduction in mean annual flow and other hydrological impacts, unlike many other regulated rivers in Victoria, the Tarago-Bunyip catchment has retained its natural seasonality (low flow in summer, high flow in winter).

Table 11 provides a summary of these changes, and greater detail is provided in Appendix 2.

Table 11 : Summary of changes to the flow regime by reach

Reach	Flow regime aspect most impacted	Change from unregulated
1 – Tarago River at Neerim	Mean annual flow	Decreased (-21%)
	Median monthly flows	Decreased (-35%)
2 – Tarago River at Neerim South	Mean annual flow	Decreased (-16%)
	Flow variability	Reduced in drier seasons
	Mid-range flows	Reduced in high flow season
3 - Labertouche Creek	Flows in general (not gauged)	Reduced
4 – Bunyip River	Mean annual flow	Decreased (-19%)
	Range of flow components	General reduction for all seasons
	Flow regime variability	Retained in low flow months
5 – Cannibal Creek	Flows in general (not gauged)	Reduced
6 – Bunyip Main Drain	Mean annual flow	Decreased (-17%)
	Median monthly flows	Decreased
	Flow variability	Reduced in low flow season
7 - Estuary	Freshwater flows and marine influence	Freshwater flows decreased Marine influence increased Sedimentation increased

Figure 24 shows a simplified model of the system, with the location of key storages and weirs, and from an operational perspective, the gauging stations and minimum flows rules.

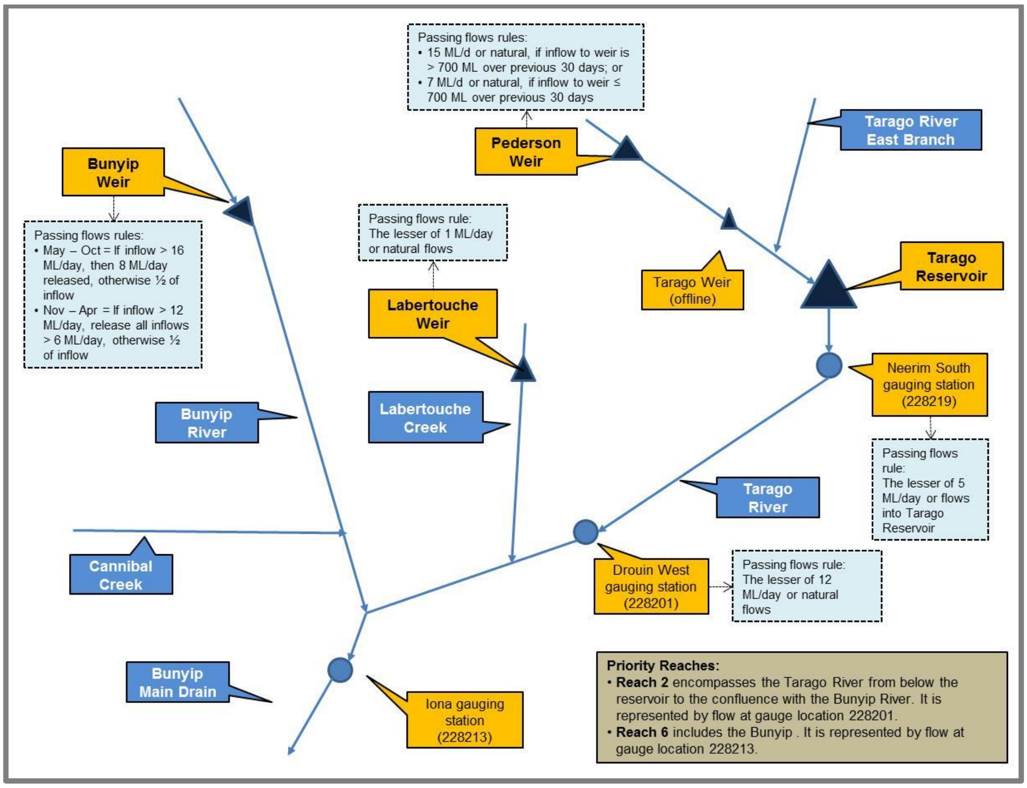


Figure 24 : Model of operational management of the Tarago-Bunyip system.

7 Estuary hydrology

The Bunyip River Estuary extends 4 km downstream from a weir at the Koo Wee Rup Water Tower, with its mouth entering Western Port in the northern arm. The estuary section of the Bunyip Main Drain is a linear, trapezoidal shaped channel downstream of the weir, opening from 10-12 m to over 30 m at the estuary mouth (EarthTech 2006a).

The tidal range in the estuary is large. During the development of the 2006 FLOWS study (EarthTech 2006a), the water heights in the estuary were measured at high and low tide over the course of a few days. On a flood tide, the water level fluctuated approximately 1.4 m, from about 20 cm depth at low tide up to 1.6 m (see Figure 25). Spring tides can see an even greater fluctuation, with maximum depths in excess of 3 m at the South Gippsland Highway.

Under very low tides the water in the estuary is dominated by freshwater surface flow and can be quite shallow; less than 0.5 m (EarthTech 2006a).

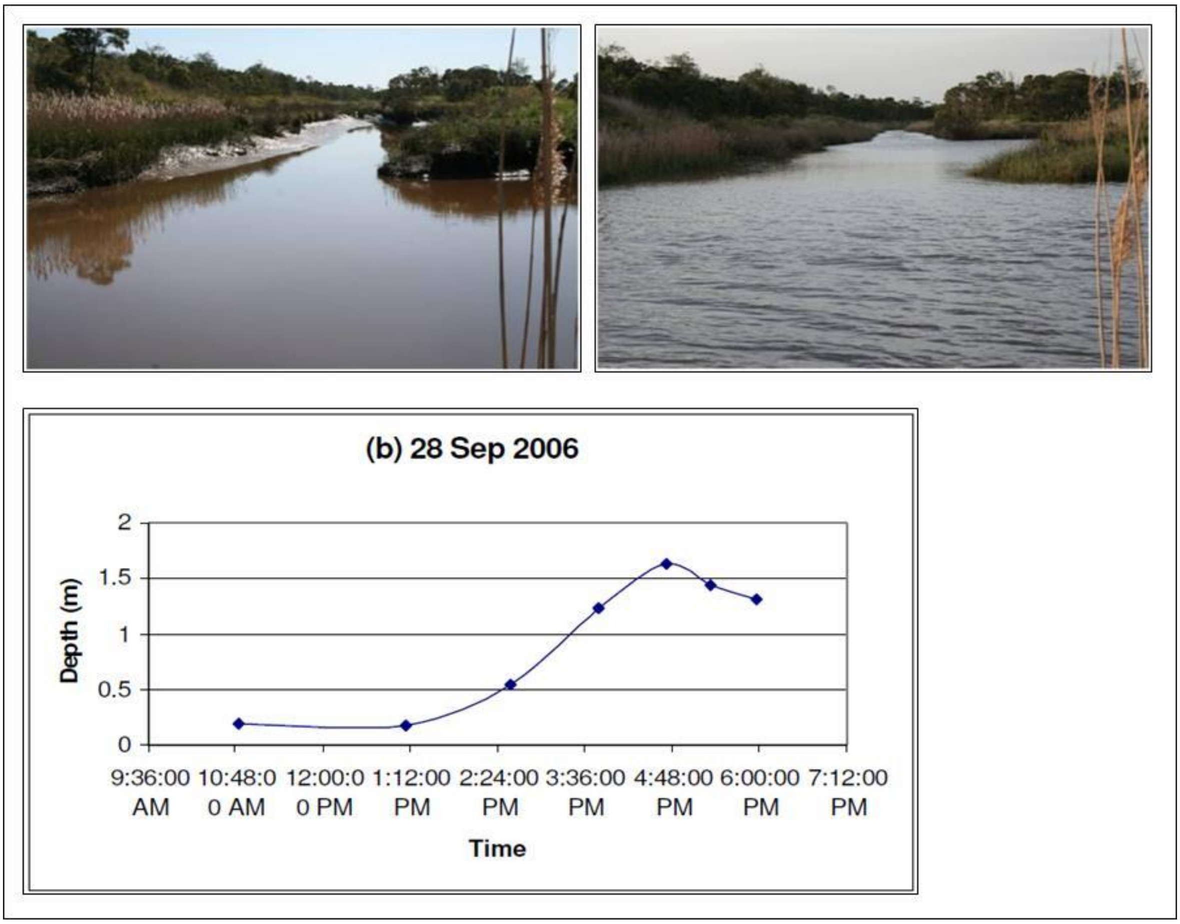


Figure 25 : Bunyip River at the South Gippsland Highway on 28 September 2006. Top left shows the estuary at low tide (approx. 11 am). Top right shows the estuary at high tide (approx. 5:20 pm). The chart (bottom) shows the depth over time. (Source: (EarthTech 2006b))

7.1 Possible consequences of altered hydrology for the estuary

EarthTech (2006a) considered the consequences of altered hydrology on the estuary, in particular the reduction in freshwater flows. It was thought that the reduction could increase the marine influence on the estuary, but this was unlikely to have a large impact on the animal species that use the estuary because being so tidally dominated, its use is more likely to be opportunistically linked to tidal patterns. The increased marine influence could however see the expansion of mangroves further up the estuary. Low freshwater discharges into the estuary were also thought to lead to increased sedimentation in the estuary, with the resulting reduction in water depth potentially impacting species that need to move through the estuary, for example Eels and Australian Grayling.

7.1.1 Management actions

Value/issue	Threat	Implication	Actions
Estuary flow requirements	Estuary flow requirements are not well defined for the Bunyip River	Inadequate and/or inappropriate flow regimes are provided to the estuary, impacting on the condition and abundance of estuarine dependent species and communities as well	• Melbourne Water will undertake a dedicated study to assess environmental flow requirements for the Bunyip estuary using the Estuary Environmental Flows Assessment Method for Victoria (EEFAM). • This will help to improve the understanding of the flow

Value/issue	Threat	Implication	Actions
		as Western Port Ramsar site species and communities	requirements in the estuary and more generally in Western Port.

8 Groundwater and surface water interactions

At the top of the Tarago and Bunyip catchment, rainfall soaks through the soil and through fractures in the outcropping granite basement rocks. The water seeps down and travels in a general southerly direction until it either reaches the regional water table, or discharges through spring flows and seeps to overlying river sediments in both rivers (GHD 2015). Deeper below the surface, groundwater continues to flow down the catchment, discharging to aquifers beneath Tynong and Cora Lynn (GHD 2015).

Southern Rural Water is responsible for managing groundwater allocations in the Bunyip and Tarago catchments. With extensive networks of groundwater bores, Koo Wee Rup Water Supply Protection Area (WSPA) was declared and a groundwater Management Plan approved by the Minister in 2002 to make sure that the groundwater resources of the area are managed in an equitable manner and to ensure their long-term sustainability. Groundwater within the WSPA is used for irrigation, dairy, industrial and stock and domestic purposes.

The time for groundwater to travel from a recharge point to a discharge point is considered to be relatively short in the Tarago-Bunyip system, ranging from less than 1 year to less than 10 years (GHD 2015). In the lower catchment at the Koo Wee Rup plains, groundwater is relatively unconfined and flows towards Western Port. Here, the aquifers are mostly saline or brackish, and beneath the coastline, a salt water / fresh water interface occurs (Figure 26).

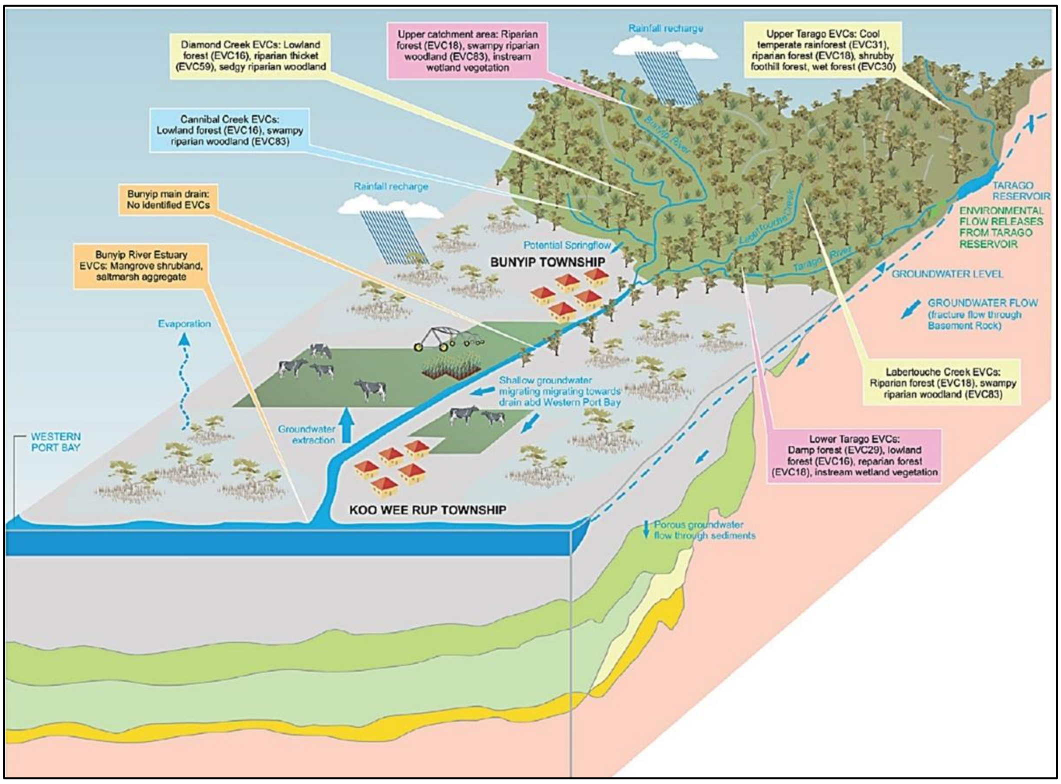


Figure 26 : Conceptual model of groundwater flow and interactions in the Bunyip catchment. EVCs that are potentially dependent on groundwater are marked. (Source: GHD 2015)

Groundwater use is typically lower than licensed allocations in the Koo Wee Rup Water Supply Protection Area (Southern Rural Water 2016).

Importantly, groundwater provides stream baseflow throughout the Tarago and Bunyip system, and helps to maintain year-round flows. Numerous information sources, such as mapping of persistent flows during previous droughts, observations by Melbourne Water staff, and data from Melbourne Water stream gauges indicate that many of the streams in the upper catchment maintained flow throughout the Millennium Drought (GHD 2015). For this reason, the Bunyip River is acknowledged as a key drought refuge because during times of low rainfall it continues to flow.

It is likely that a significant proportion of low flows are derived from the upper catchment area, from a combination of groundwater contributions and environmental flow releases from Tarago Reservoir. It is worth noting here that there are minimal groundwater extractions in this area. Maintaining these upper catchment sources of low flows is thus as important, if not more so, than maintaining baseflows to the already impacted lower catchment (GHD 2015).

8.1 Groundwater dependent ecosystems

Groundwater contributions to stream baseflow help to maintain instream habitat, migratory passage, and the condition of riparian vegetation, particularly during dry climatic periods (i.e. provide drought refugia). Further away from the instream channel, groundwater can also support above-ground and below-ground biota on the floodplain and even further afield. The ecosystems which depend on a source of groundwater for their water requirements are referred to as Groundwater Dependent Ecosystems (GDEs).

The surface water-groundwater interactions for the Bunyip and Tarago system are complex, either gaining or losing to groundwater depending on factors such as surrounding geology, location within the basin, topography, groundwater extraction and irrigation intensity (GHD 2015). Assessment of the gaining and losing reaches has shown a generally consistent trend between wet and dry periods, with mostly gaining conditions in the upper catchment, and mostly losing conditions and fluctuating reaches in the lower catchment (GHD 2012). These relationships are illustrated in Appendix 7.

The Tarago and Bunyip Rivers have three different types of GDEs:

- Terrestrial vegetation – vegetation communities that obtain at least part of their water requirements from groundwater and are not totally reliant on surface waters
- River baseflow systems – Aquatic and riparian ecosystems that are dependent on groundwater-derived stream flow or bank storage for their baseflow. This includes hyporheic[13] communities associated with the river beds and banks
- Cave ecosystems – Known to exist in the granite Labertouche Caves, which occur within a tributary of Labertouche Creek that flows underground (GHD 2015).

A number of different values associated with these GDE types are discussed below.

Aquatic fauna

Aquatic fauna in waterways generally require permanent flow, particularly in the lower reaches. Groundwater levels in the riparian zone may be important in maintaining habitat for burrowing crayfish for example, and persistent flow is needed to facilitate migration of native fish. The persistent low flows from the upper catchment flowing into the lower catchment area may be the dominant source of low flows because of the relatively flat groundwater gradients and significant losing reaches in the lower catchment.

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[13] The hyporheic zone is a region beneath and alongside a stream bed, where there is mixing of shallow groundwater and surface water.

Riparian vegetation

Riparian and wetland vegetation is likely to be dependent on a combination of stream water, groundwater and rainfall (GHD 2015). The majority of reaches in the upper Bunyip and Tarago Rivers are considered 'gaining', which, coupled with shallow groundwater levels, shows potential for groundwater contributions to surface water and thus a role in maintaining the ecological values of the riparian area (GHD 2015).

Stygofauna in the Labertouche Granite Caves

Stygofauna are small aquatic animals that live in groundwater. It has not been confirmed if stygofauna are present within the catchment, but conditions within the Labertouche Granite Caves are thought to provide suitable habitat. With many of these communities having small distribution ranges, they can be particularly vulnerable to extinction from environmental changes and human impacts. Previous studies have recommended that the potential for stygofauna be assessed at Labertouche Creek (GHD 2015).

Mangrove interactions with groundwater

Mangroves generally occur in estuarine areas subject to tidal flooding. While seawater is the primary source of water, groundwater can also be an important source of freshwater in these ecosystems. SKM (2012) concluded that while shallow groundwater exists across Western Port Bay and at the terrestrial and coastal interface, there is no direct evidence of how groundwater and the coastal environments interact.

Saltmarsh interactions with groundwater

Saltmarsh communities can tolerate high salinity and inundation by marine or brackish water, and they are generally located within estuaries or along high tide zones. There is evidence that groundwater inputs to these communities provides critical sources of nitrogen, but same as for mangroves, little is known at present about the interactions between coastal saltmarsh and groundwater in the lower Bunyip system (GHD 2015).

8.1.1 Management actions

Groundwater-surface water interactions will be important to review more thoroughly for understanding flow requirements in the lower Bunyip and estuary. It will also be important to better understand the implications of urban development in the upper catchment, particularly given a significant proportion of low flows are derived from groundwater originating from these areas. Urbanisation, with its associated increases in impervious surfaces, can have significant impacts on groundwater infiltration.

Value/issue	Threat	Implication	Actions
Groundwater / surface water interactions	• Bushfire and timber harvesting in the upper catchment changing the rates and pattern of groundwater recharge • Urbanisation and land use change decreasing recharge in the mid catchment, reducing baseflows in reaches downstream	Loss of habitat for GDEs	• Melbourne Water will continue to work with key delivery partners to increase knowledge and understanding of the likelihood, risks and consequences of this threat.

9 The history of environmental water delivery

The Victorian Government's Central Region Sustainable Water Strategy identified the Werribee, Maribyrnong, Tarago and Yarra Rivers as high priority waterways for enhanced Environmental Water Reserves for the Melbourne region because they were considered by Government to be fully allocated (DSE 2006). The Central Region Sustainable Water Strategy (SWS) also committed 3000 ML towards improving the condition of the Tarago and Bunyip Rivers.

The first flow recommendations for the system were determined by EarthTech in 2006 (EarthTech 2006a). On 11th March 2009, the then Victorian Minister for Water endorsed the *Tarago and Bunyip Rivers Environmental Entitlement 2009*. The entitlement came into operation on 1st May 2009, but at reduced passing flows because of drought contingency requirements at the time, which were aimed at conserving water for supply during the Millennium Drought.

The entitlement contains:

- A minimum passing flow of 12 ML/day (or natural) at Drouin West gauging station
- 10.3% of the net inflow into the reservoir, once passing flows have been met
- A 3 GL share of Tarago Reservoir.

The full entitlement was instated on 2nd April 2010 after the completion of Melbourne's Desalination Plant in Wonthaggi and the lifting of Stage 3a restrictions on Melbourne customers.

In addition to the above entitlement volumes, in 2011 the Victorian Environmental Water Holder (VEWH) was successful in negotiating access to airspace in the Tarago Reservoir. Previously, all inflows above 3 GL spilled into the water retailers' share (in this case City West Water, South East Water and Yarra Valley Water).

9.1 Environmental water delivery operating arrangements

Managing and delivering environmental water requires careful planning. As the Waterway Manager for the Tarago/Bunyip system, Melbourne Water is responsible for developing and implementing the Healthy Waterway Strategy, the Environmental Water Management Plan, and the Seasonal Watering Proposal. Seasonal watering proposals are required under Section 192A of the Water Act 1989. The Seasonal Watering Proposal outlines Melbourne Water's annual priorities for the use of the Bunyip-Tarago Environmental Entitlement. It is used by the VEWH to inform the development of its Seasonal Watering Plan, which outlines the full scope of statewide priorities for the use of environmental Water Holdings in any year. Melbourne Water is also responsible for planning the implementation of specific watering activities for each watering year. As part of its delivery planning and implementation, Melbourne Water reviews, updates and implements any risk mitigation actions identified in the Seasonal Watering Plan.

9.1.1 How is the system managed operationally?

Inflows to Tarago Reservoir are tracked on a seasonal basis against historic inflows, representing very dry, dry, average and wet conditions. Tracking on a seasonal basis allows for changes in conditions to be detected faster than tracking on an annual basis. A decision support tree is used, and maps out how this information determines decisions around watering actions each year. This is shown in Appendix 3.

Chapter 4 - Vision and Management Objectives

Environmental flows benefit both people and nature, and it is increasingly clear that, in the mid to long term, failure to meet environmental flow requirements has serious consequences for many river users. When managing environmental flows, it is important to consider all aspects of a river and its drainage system within context. A wide range of outcomes, from environmental protection and resilience against the threats of climate change, to serving the needs of industries and people need to be considered when determining management objectives.

10 Vision for the Tarago and Bunyip Rivers

Environmental flows must be seen within the context of applying integrated water resource management in a catchment. They will only ensure a healthy river if they are part of a broader package of measures, such as soil protection, community capacity building, pollution prevention, and protection and restoration of habitats. For the Tarago and Bunyip waterways, much has also depended on stakeholders' decisions about the future character and health status of these ecosystems. Scientists and experts have helped inform these decisions by providing information and knowledge on how the system is likely to evolve under various flow conditions, and our knowledge of just how crucial environmental flows are to sustainable development and the long-term prosperity of communities is always improving.

Where Melbourne Water has the opportunity, shared benefits are incorporated into the seasonal watering planning process. For example, releases were timed for the Australia Day long weekend to coincide with community use of the Tarago River for swimming and picnicking at Drouin West.

The vision for the Tarago and Bunyip system reflects the complexity of uses and values it provides, and also reflects how the catchment is seen by the people who live and work there. Appendix 4 shows a series of 'Vision Boards' created by people participating in the consultation process for the development of the EWMP. The Vision Boards reflect the importance of the waterways for community health and wellbeing and for economic and environmental health. They also provide a snapshot of where people would like to see the waterways in 20 years' time.

The key management themes from this visioning exercise, as well as a range of other consultation discussions held during the development of the EWMP are summarised in Table 12 and shown in Appendix 4.

Table 12 : Key management themes and visions for the Tarago and Bunyip Rivers in 20 years' time, as articulated via visioning exercises held during the development of the EWMP

Management objective	Vision for the waterways in 20 years
The waterways are protected from damage	• Stock (e.g. cattle) are excluded from the waterways • Weeds and pests have been eradicated • There is less rubbish in and around the waterways • Stormwater issues are better managed, reducing their impact on receiving waters

Management objective	Vision for the waterways in 20 years
	• Reduced sediment loads are entering Western Port • Pest animals such as deer are eradicated from the upper reaches of the Bunyip River
High conservation value species are protected	• The Bunyip Main Drain provides habitat that supports key species and ecosystem functions. • There are increased and stable populations of threatened species such as Australian Grayling, Dwarf Galaxias, Warragul Burrowing Crayfish and Southern Toadlets.
Flagship species are protected	• Platypus populations persist and are improving in numbers and health • Platypus populations are also more visible for the community
Education, engagement and community awareness regarding the values of the waterways is improved	• Community understanding, awareness and appreciation of the waterways is improved • There is strong inter-neighbour co-operation, particularly for revegetation activities • There is increased community knowledge and appreciation of environmental water and habitat values within the waterways • There is improved education regarding the environmental and historical significance of the area • There is a greater understanding and awareness of the Aboriginal cultural values of the waterways, with incorporation of these values into the EWMP and Seasonal Watering Plan • There are improved opportunities for recreation along the waterways, such as walking, cycling and swimming, with interpretive signage
Wildlife corridors and habitat connectivity are improved	• There is good connectivity of vegetation between catchments for Helmeted Honeyeaters and Southern Brown Bandicoots
Good quality habitat is provided	• Healthy streamside vegetation • Water quality provides great habitat conditions for aquatic animals • Diverse aquatic habitat – pools, riffles, bends and woody debris, with good water quality, water bugs, vegetation, platypus, fish, river banks
The impacts of Climate Change are better understood, and management actions are in place to address vulnerabilities and risk	• Climate change impacts are better understood - in terms of its likely effects on flow regime • The vulnerability of key species to the impacts of climate change is better understood and management actions to mitigate the risks of these vulnerabilities have been implemented • Environmental water shortfalls have robust estimates, and strategies are in place to address these shortfalls
The waterways are collaboratively managed with Traditional Owners	• Aboriginal peoples' expectations and management objectives for the waterways are understood and incorporated into the environmental watering program and broader waterways management program • Water-dependent cultural values are known for the waterways, including the appropriate flow regimes to protect and/or improve these values

Management objective	Vision for the waterways in 20 years
	• Aboriginal and non-Aboriginal people work together to protect and manage the waterways for their ongoing health and productivity, providing a range of cultural, social, economic and environmental benefits.

10.1 Vision Statement

The feedback received during the development of the EWMP indicated that the Tarago and Bunyip Rivers should be managed differently depending on catchment context, reflecting the different land uses and values present. North of the Gippsland Rail Line, the waterways and their surrounding areas are less impacted by land clearing and agriculture and have significant biodiversity values remaining, particularly in the upper reaches of both waterways and the tributaries. South of the Gippsland Rail Line, where Koo Wee Rup Swamp once was, the land has been significantly cleared and developed. Here, the Bunyip Main Drain and Estuary essentially function as a 'working river', providing passage for Australian Grayling and some habitat for Southern Brown Bandicoots, platypus and other biota, but mainly managed for their role as part of the local drainage and flood management system.

Reflecting the dual nature of the waterways and community expectations, the Vison Statement is divided into two parts.

Upper catchment

North of the Gippsland Rail Line, the upper reaches of the Bunyip and Tarago Rivers are valued by our community for their high biodiversity and cultural values and the unique species and we recognise that the long-term condition of these values depends greatly on a secure water source. We will work to protect and where possible restore and enhance the ecological health and function of these reaches, so that they continue to support a rich diversity of self-sustaining indigenous species and the important ecosystem services they provide.

Lower catchment

South of the Gippsland Rail Line, the lower reaches of the Bunyip River and Estuary play an important role in our community, supporting livelihoods and protection from floods. Although highly modified, these parts of the catchment still provide important habitat for endangered species, and we will use our environmental water to protect and improve the quality, connectivity and abundance of their habitat. We will work to cultivate community awareness of the importance of these reaches, in terms of the intrinsic social, economic and environmental value they provide.

11 Ecological objectives

The key values of amenity, fish, birds, frogs, macroinvertebrates, platypus and vegetation in Melbourne Water's Healthy Waterways Strategy provide the foundation for the EWMP management objectives. Summaries of these objectives are shown in Table 13 for the upper Bunyip River and Tarago River (the upper catchment), and Table 14 for the lower Bunyip River and estuary (the lower catchment). For more detail on how each of the condition ratings have been determined, please refer to the Healthy Waterways Strategy (Melbourne Water 2013).

Table 13 : Healthy Waterways Strategy management objectives for key values in the Upper Tarago and Bunyip management area

Values	HWS objective	Priority areas?	Current condition	Expected condition in 20 years
HWS values – Upper Bunyip and Tarago				
	**Maintain high species richness** and abundance of fish populations	• Bunyip and Tarago Rivers above confluence	Very High	Very High
	**Stabilise or increase relative abundance** of platypus population.	• Labertouche Creek • Tarago River • Upper Bunyip River	Very Low	Low
	Works over the next 20 years aim to **improve condition from moderate to high**, and very high in the long-term	• Bunyip River headwaters above Diamond Creek confluence • Labertouche Creek, • Tarago River and Middle Bunyip River • Cannibal Creek	Moderate	High
	Works to protect and improve water quality and habitat aim to **raise this condition from high to very high** in the next 20 years	• Bunyip River at Bunyip State Park	High	Very High
	**Improve condition to high** over the next 20 years through improvements in floodplain habitat	• None provided	Moderate	High
	**Maintain moderate condition** over the next 20 years with improvements in the longer term.	• None provided	Moderate	Moderate
	High amenity values are still provided and reserved through natural forests, picnic areas along rivers and streams and vistas along waterway corridors. **Maintain condition at high.**	• None provided	High	High
Habitat quality and availability values (FLOWS study objectives only)				
Physical form	Improve habitat and stability from good to excellent in upper reaches (Tarago River). Maintain good quality habitat and stability (upper Bunyip)	N/A	N/A	N/A
Water quality	Maintain moderate to good condition of water quality	N/A	N/A	N/A

Table 14 : Healthy Waterways Strategy management objectives for key values in the Lower Bunyip management area

Values	HWS objective	Priority areas?	Current condition	Expected condition in 20 years
HWS values – Lower Bunyip				
	Works aim to **maintain condition** over the next 20 years. Works to improve habitat and fish passage may result in migratory species such as smelt and lamprey being recorded again.	None provided in HWS	High	Very High
	Works aim to **stabilise this population** to allow for improvement over the long term	Middle Bunyip River	Very Low	Very Low
	Works concentrating on streamside revegetation will aim to **improve condition to moderate** over the next 20 years	None provided in HWS	Very Low	Moderate
	Improvements in streamside vegetation and stormwater management – therefore habitat and water quality – aim to improve condition from **moderate to high** within the next 20 years	None provided in HWS	Moderate	High
	Frog species diversity is very high. **Maintaining this condition** over the next 20 years and beyond will be the focus of floodplain works.	None provided in HWS	Very High	Very High
	The number and variety of species is very low. Works to improve habitat aim to **raise this condition to low** over 20 years and moderate in the long term	North Western Port coastal fringe	Very Low	Low
	Actions targeted at improving vegetation will **increase the condition to moderate** in the long term, but the small amount of public land and limited access to waterways will restrict the overall gain possible.	None provided in HWS	Low	Low
Habitat quality and availability values (FLOWS study objectives only)				
Physical form	Improve habitat and stability from moderate to excellent in lower reaches (Bunyip River).	N/A	N/A	N/A
Water quality	Improve water quality from very poor to poor	N/A	N/A	N/A

The Tarago and Bunyip FLOWS study has provided the more targeted ecological objectives for the system, including draft objectives being provided for the estuary (EarthTech 2006a). In 2013, the ecological objectives were reviewed to incorporate relevant new knowledge (SKM 2013). These studies have focused on determining ecological objectives and flow recommendations for vegetation, fish, macroinvertebrates and platypus (Reach 6 only), as well as geomorphology and water quality. Geomorphology is a key value because of its role in the provision and maintenance of good quality habitat, but it is not specifically recognised as a value in the Healthy Waterways Strategy. Ecological objectives for birds, frogs and amenity were not recommended because of insufficient knowledge at the time, an issue that remains for the EWMP. This paucity of information is considered to be a knowledge gap, and is discussed further in Section 0. Environmental flow recommendations are based on the assumption that particular flow components are able to provide an ecological function that then contributes towards the achievement of ecological objectives. Figure 27 shows the flow of logic and assumptions for ecological objectives and flow components.

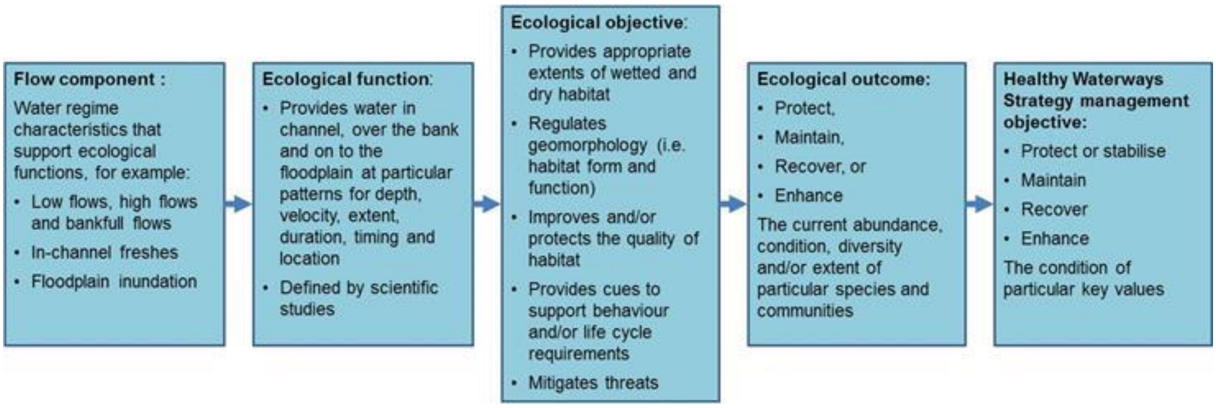


Figure 27 : Program logic for environmental watering actions

11.1 Prioritising reaches for receiving flows

Due to a lack of hydrological data at the time of the original FLOWS study, Reaches 3 and 5 - Labertouche and Cannibal Creeks - have not yet had environmental flow recommendations developed. At the time of the development of the EWMP a study was underway on Cannibal Creek to quantify environmental flow recommendations (Jacobs Draft in Prep 2017). A gauging station has also been measuring flows on Labertouche Creek since 2011 which will be incorporated into future FLOWS study reviews. Reach 7, the Bunyip Estuary, has not yet had a formal environmental flow study undertaken, but still benefits from releases made through the upstream system.

There is not enough water held in storage for the Tarago-Bunyip Environmental Entitlement to comply with every flow component every year, or to water every reach within the system, so Melbourne Water takes into account the antecedent climate conditions, the current condition of key values, the ease of providing water, and the amount of water held in storage to help prioritise releases.

While ecological objectives and flow recommendations have been determined for the upper reaches of both Tarago (Reach 1) and Bunyip rivers (Reach 4), the hydrological regime of these reaches is not as severely impacted by diversions and storages as the lower reaches. Combined with the difficulty of providing water to these reaches, they are a lower priority for environmental watering.

The priority reach for environmental watering is Reach 2, the Lower Tarago River from Tarago Reservoir to the Bunyip River confluence. This reach has significant environmental values and is the reach most influenced by water released from Tarago Reservoir. Some benefit can also be provided to the lower Bunyip River (Bunyip Main Drain, Reach 6) and the Bunyip Estuary (Reach 7), as these lie downstream of Reach 2. The measurement point for target flows in Reach 2 is at Drouin West. Reach 6 and Reach 7 receive the environmental releases from Tarago Reservoir via Reach 2, and also receive unregulated flows from the Bunyip River.

11.2 Flow recommendations

The ecological objectives and flow components for priority reaches are summarised in Table 15.

Appendix 8 provides the full flow recommendations, as well as summarised management objectives for each of the Tarago/Bunyip system's seven key values, linking reaches to the related ecological objectives and ecological functions. Note that because the key values of frogs, birds and amenity do not receive specific flow recommendations in the FLOWS studies, the ecological objectives for these values are kept more generic for this EWMP. These focus on the need to rehabilitate, maintain or improve access to habitat, as well as protect and improve its quality.

As additional knowledge is gained on the flow requirements of frogs, birds and amenity, Melbourne Water will ensure they are incorporated for consideration in future FLOWS study reviews.

Table 15 : Priority environmental objectives and flow components for Reach 2 and Reach 6

Reach	Flow component	Climate scenarios (very dry, dry, average and wet)	Magnitude (ML/day)	Duration (days)	Frequency	Timing	Tolerance between events	Associated environmental objectives	Is the flow component consistent with the environmental flow study or EWMP
2	Summer / Autumn Low	Continuous event provided by passing flows.	12 or natural	All season	Continuous	Dec-May	Continuous event provided by passing flows.	Habitat availability and movement for river blackfish, platypus, macroinvertebrates and Australian Grayling. Water quality	Y - Earth Tech, 2007
6	Summer / Autumn Low[!]	Continuous event provided by passing flows.	50 or natural	All season	Continuous	Dec-May	Continuous event provided by passing flows.	Habitat availability and movement for river blackfish, platypus, macroinvertebrates and Australian Grayling. Water quality	Y - Earth Tech, 2007
2	Summer / Autumn fresh	Very dry to wet	100	4	5	Dec-May	Unknown	Prevent vegetation growing on sandbars.	Y - Earth Tech, 2007
6	Summer / Autumn fresh[!]	Very dry to wet	120	7	3	Dec-May	Unknown	Habitat availability	Y - Earth Tech, 2007
2	Autumn high	Dry to wet	100	2	1	Apr - May	2 (occurs 3 out of 4 years)	Spawning trigger for downstream dispersal of Australian Grayling	Y – Flow recommendations reviewed and amended by SKM 2013.
6	Autumn high[!]	Dry to wet	200	2	1	Apr - May	2 (occurs 3 out of 4 years)	Spawning trigger for downstream dispersal of Australian Grayling	Y – Flow recommendations reviewed and amended by SKM 2013.

Reach	Flow component	Climate scenarios (very dry, dry, average and wet)	Magnitude (ML/day)	Duration (days)	Frequency	Timing	Tolerance between events	Associated environmental objectives	Is the flow component consistent with the environmental flow study or EWMP
2	Winter / Spring low	Average to wet year	100	All season	Or natural	Jun - Nov	Unknown	Prolonged wetting of banks to prevent terrestrial species, fish passage and water quality	Y - Earth Tech, 2007
6	Winter / Spring low	Average to wet year	50 (Jun-Sept) 70 (Oct-Nov)	All season	Or natural	Jun - Nov	Unknown	Prolonged wetting of banks to prevent terrestrial species, fish passage and water quality	Y - Earth Tech, 2007
2	Winter / Spring fresh	Wet year	280	3	3	Jun - Nov	Unknown	Habitat inundation – variability to provide zonation.	Y – Earth Tech 2007 and reviewed and amended by SKM 2013.
6	Winter / Spring fresh [!]	Wet year	170	2	2	Jun - Nov	Unknown	Prevent sedimentation to provide sufficient depth for fish passage.	Y – Earth Tech 2007 and reviewed and amended by SKM 2013.
2	Spring high	Average to wet year	280	4	1	Oct - Dec	Unknown	Upstream trigger for Australian Grayling.	Y – Earth Tech 2007 and reviewed and amended by SKM 2013.
6	Spring high	Average to wet year	240	4	1	Oct - Dec	Unknown	Inundate barriers and provide access for fish.	Y – Earth Tech 2007 and reviewed and amended by SKM 2013.
2	Bankfull [#]	Wet year - not actively delivered	600	1	1	Anytime	Unknown	Wetting of banks to encourage flood tolerant species.	Y – Earth Tech 2007 and reviewed and amended by SKM 2013.

Reach	Flow component	Climate scenarios (very dry, dry, average and wet)	Magnitude (ML/day)	Duration (days)	Frequency	Timing	Tolerance between events	Associated environmental objectives	Is the flow component consistent with the environmental flow study or EWMP
6	Bankfull #	Wet year - not actively delivered	1500	1	1	Anytime	1 in 2 years		Y - Earth Tech, 2007
2	Overbank #	Wet year - not actively delivered	1000	1	1 in 2 years	Anytime	Unknown	Inundate floodplain habitats and prevent gross channel change.	Y - Earth Tech, 2007
6	Overbank #	Wet year - not actively delivered	N/A	N/A	N/A	N/A	N/A	N/A	N/A

Bankfull and overbank flow components are not delivered as part of the Environmental Entitlement but are included for completeness.
! Not actively delivered - rely on reach 2 delivery and reach 4 natural contributions.

12 Adaptive management of environmental water releases

Environmental water delivery is monitored and adaptively managed as conditions unfold throughout the year and four management scenarios have been developed to cover a range of possible climatic conditions for the system. The scenarios and the watering actions associated with them are outlined in Table 16 and are based on historic streamflow in Reach 2. Throughout the year, Tarago Reservoir inflows, streamflows in Reach 2 and Bureau of Meteorology seasonal forecasts are used to determine which scenario to manage towards.

The four climatic scenarios are determined by comparing current conditions to historic streamflow data for Reach 2 and Reach 6. The four scenarios are:

1. Drought –lowest 5th percentile of flows;
2. Dry – between 5th and 35th percentile of flows;
3. Average – between 35th and 65th percentile of flows; and
4. Wet – highest 65th percentile of flows.

A decision support tree is used to analyse climatic conditions and determine watering actions. This is shown in Appendix 3.

12.1.1 Management actions

Protecting environmental releases throughout the length of the system will be important in ensuring the maximum ecological benefit is achieved.

Value/issue	Threat	Implication	Actions
Protecting environmental flow releases	Environmental flow releases are diverted out of the waterway by irrigators	Poor compliance with environmental flow recommendations and subsequent impacts on ability to achieve ecological objectives	• Melbourne Water will consult with Southern Rural Water (SRW) to better understand the impacts and risks of diversions occurring during releases. • Melbourne Water will also complete a project in 2017/18 examining the relationship between flow compliance and ecological outcomes, to better understand the consequences of poor flow compliance under a variety of flow scenarios.

Table 16 : Delivery of priority watering actions under a range of current climatic scenarios

	Drought **(Lowest 5th percentile of flows)**	**Dry** **(Between 5th and 35th percentile of flows)**	**Average** **(Between 35th and 65th percentile of flows)**	**Wet** **(Highest 65th percentile of flows)**
Expected water availability	**Carryover** 1,500 ML **Inflows** 200 ML	**Carryover** 1,500 ML **Inflows** 500 - 1,000 ML	**Carryover** 1,500 ML **Inflows** 1,000 - 2,200 ML	**Carryover** 1,500 ML **Inflows** 2,300 – 3,500 ML
Watering actions to be delivered	• Summer / autumn freshes as required to provide relief from long periods of low streamflow	• Summer / autumn freshes as required to provide relief from long periods of low streamflow • Autumn high for migratory fish spawning (partial achievement)	• Summer / autumn freshes • Autumn high for migratory fish spawning. (partial achievement) • Spring high for fish migration (partial achievement)	• Summer / autumn freshes • Autumn high for migratory fish spawning • Spring high for fish migration • Winter / spring freshes to discourage terrestrial vegetation Bankfull and overbank may occur naturally but will not be provided
Environmental objectives	• Protect priority species and critical refuge habitat • Prevent localised extinctions and catastrophic events, such as fish kills. • Protect water quality to prevent adverse impacts on priority species and habitats	• Protect priority species and critical refuge habitat • Prevent localised extinctions and catastrophic events, such as fish kills • Protect water quality to prevent impacts on priority species and habitats	• Improve access to suitable habitat for priority fauna • Protect against flow related declines in water quality • Maintain habitat connectivity • Increase zone of flood tolerant vegetation, by drowning out encroaching terrestrial species • Provide flows for spawning and migration of priority fish species	• Improve access to suitable habitat for priority fauna • Maintain habitat connectivity • Increase zone of flood tolerant vegetation, by drowning out encroaching terrestrial species • Provide flows for spawning and migration of priority fish species • Maintain channel geomorphology
Water volume to be delivered	1000 ML	1000 - 1500 ML	1500 - 2700 ML	0 - 3500 ML

	Drought (Lowest 5th percentile of flows)	Dry (Between 5th and 35th percentile of flows)	Average (Between 35th and 65th percentile of flows)	Wet (Highest 65th percentile of flows)
Additional watering actions that may be delivered if more environmental water was allocated	Spring high for fish migration (partial achievement)	Spring high for fish migration (partial achievement) Autumn high for migratory fish spawning (full achievement)	Spring high for fish migration (full achievement)	N/A

Chapter 5 – Managing for Climate Change

Victoria's climate is changing and the climatic conditions Melbourne Water uses to determine flow releases are shifting. With conditions becoming hotter and drier, changes in rainfall are amplified when translated into changes in catchment runoff and streamflow, which has serious consequences for values dependent on waterways for their survival. This section provides the results of an analysis for the Tarago and Bunyip system that was undertaken specifically for the development of the EWMP.

13 Climate outlook

The global average combined land and ocean surface temperature shows a warming of 0.85°C over the period 1880 to 2012 (IPCC 2014), with local temperature trends in Victoria showing similar patterns (Grose 2015, Timbal *et al.* 2016). Scientists have observed that climate change can occur as both gradual and step changes. In Victoria it appears that there may have been step changes in climate that occurred in the mid 1970's and again after 1997. These changes have resulted in a reduction in cool season (April to October) rainfall over recent decades. This phenomenon was particularly evident during the Millennium Drought, but is now thought to be continuing in many parts of Victoria (Timbal *et al.* 2016).

Although there are uncertainties associated with climate change predictions, trends for the Greater Melbourne region have been interpreted from a range of climate models and studies focused on climate change impacts (Howe *et al.* 2005, CSIRO 2012, Wales *et al.* 2012, CSIRO and Bureau of Meteorology 2015, Potter *et al.* 2016). These trends are summarised in Table 17.

Table 17 : Climate change threats and trends for Melbourne

Threat	Trend
Drought and reduced rainfall	• The number of annual rainy days is predicted to decrease by 6% by 2030, and 10-19% by 2070, • Reductions in average stream flow of 3-11% by 2020 and 7-35% by 2050 • Up to 50% less runoff into the Bunyip, Yarra, Maribyrnong and Werribee Rivers by 2070
Extreme temperature rise	• Higher average annual temperatures, with an increase of 0.3-1.0°C by 2020, and 0.6-2.5°C by 2050 • An increase in annual number of days above 35°C from 9 days to 10-13 days by 2030, 15-26 days by 2070, and 16-33 days by 2100
Intense rainfall	• An increase rainfall intensity of 0.9% by 2030 and 3.0-5.9% by 2070
Sea level rise	• A rise in sea level of up to 1.1 metres by 2100

Historical changes in the runoff in Victorian streams, particularly over the Millennium Drought, have been well documented. They have been presented in each year's

Victorian Water Accounts (e.g. DELWP (2015b)), with the statistical significance of a step change in streamflow identified in several studies, including the CSIRO Murray-Darling Basin Sustainable Yields project (CSIRO 2008), and the Bureau of Meteorology at its hydrologic reference stations across Victoria (Bureau of Meteorology 2016).

Figure 28 illustrates the magnitude of changes in streamflow over the Millennium Drought for inflows to Melbourne's main harvesting storages. The inflows over this period were on average around 35% lower than the long-term average, with no single year of inflows above the long-term average.

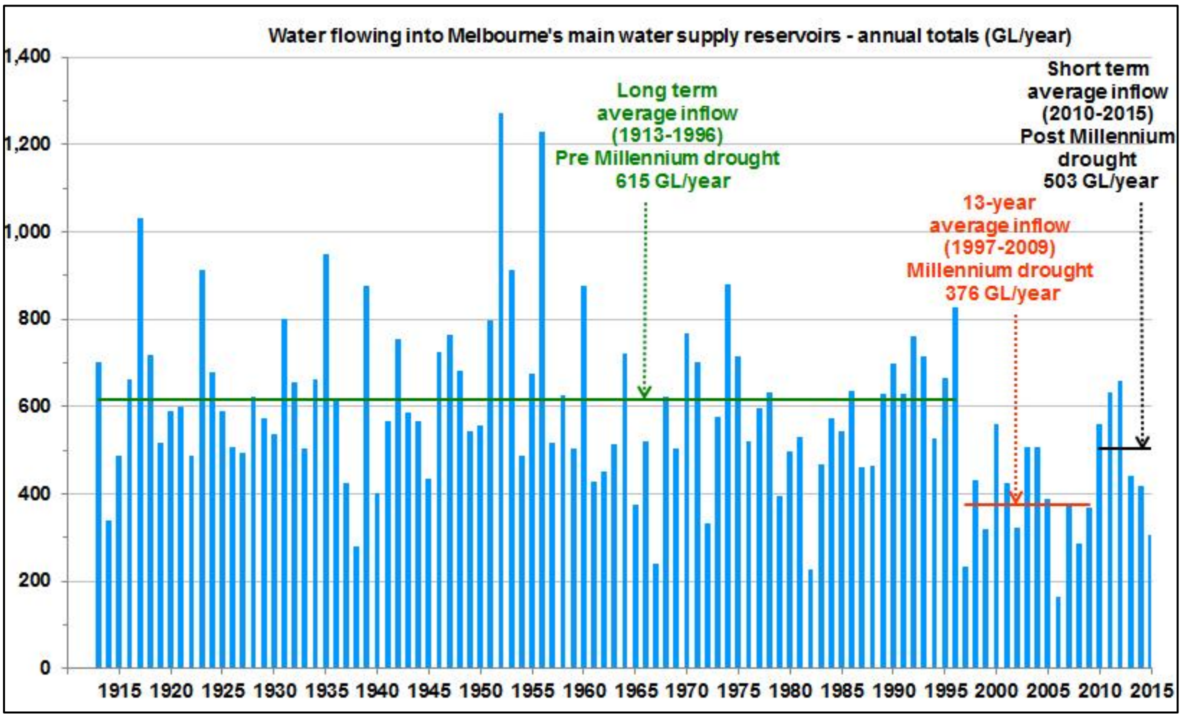


Figure 28 : Annual inflows to Melbourne's main water supply reservoirs (Source: (Melbourne Water 2017)

Medium and high climate change scenarios show a decrease in rainfall and runoff across all of Victoria by 2040, with the greatest impacts seen in western Victoria. The low climate change scenario projects a small increase in rainfall and runoff across Victoria in 2040 and 2065 (Table 18).

Table 18 : Projected changes in average annual runoff relative to the current climate baseline across all seasons for the Bunyip/Tarago catchment (Source: DELWP 2016)

Average annual runoff (mm) (1975-2014)	Change relative to current climate baseline (%)					
	Year 2040			Year 2065		
Historic	10th percentile (Wet)	50th percentile (Medium)	90th percentile (Dry)	10th percentile (Wet)	50th percentile (Medium)	90th percentile (Dry)
227 mm	+10.0%	-11.0%	-29.2%	+0.8%	-16.4%	-44.3%

13.1 The impacts of climate change on Tarago and Bunyip flows

Modelling of climate change impacts on Tarago / Bunyip system flows (environmental flow Reaches 2 and 6) was undertaken for the EWMP by taking the current flow regime and applying a flow reduction consistent with the predicted runoff reductions in Table 18. The scenarios were then analysed to see how well flow regimes complied with current environmental flow recommendations, using a compliance assessment process developed by Jacobs for the Tarago River and currently used by Melbourne Water to assist in seasonal flow planning.

In Reach 2, and under current conditions, compliance with summer low flows and summer high flows is generally good, except in the driest of years. In most average and wet climate years, winter high and bankfull flows are also achieved. Compliance with winter low flows and summer and winter freshes is generally moderate. Under climate change there is a relatively small reduction in compliance under the 2040_medium climate change outlook, but by 2065 under both medium and dry outlooks there is a significant decrease in compliance with flow recommendations, including in wet climate years. Table 19 shows the results of the analysis for Reach 2.

In Reach 6 under current conditions there is an overall improvement in compliance compared to Reach 2. This is because of the increased unregulated tributary flows from the upper Bunyip River. There is a small reduction in compliance under the medium climate change outlook. However, under the dry climate change outlook there is a large reduction in compliance, especially with summer fresh and high flows. Table 20 shows the results of the analysis for Reach 6.

The ecological consequences of climate change impacts are likely to be most severely felt in Reach 2, where there are likely to be large reductions in flow variability and an overall reduction in availability of habitat for resident fish, macroinvertebrates and platypus. Impacts in Reach 6 may be not as severe, but under the dry climate outlook a reduction in summer freshes and particularly summer high flows could significantly impact on migration and spawning cues for the threatened Australian Grayling.

The ability to deliver environmental flows under climate change are discussed in the next section.

13.1.1 Shortfalls with flow recommendations

An assessment of the magnitude of the annual shortfall (the volume of water required to deliver all environmental flow recommendations) was made. Shortfall volumes were calculated for current conditions and climate change scenarios but were not determined for bankfull or overbank flow recommendations because the Environmental Water Reserve is not currently used to deliver these types of flow events. The shortfalls are presented as box plots that show the range of annual shortfall volumes under current and various climate change scenarios (Figure 29).

The analysis shows that in both Reaches 2 and 6 for summer under current conditions there is very little shortfall in delivery of low flow recommendations. This is because low flows are currently delivered as a passing flow requirement, which is also reflected in the high compliance with summer low flows. However, shortfalls with winter low flows in Reach 2 are relatively high: the winter low flow recommendation is 100 ML/d and on average a flow of only around 70 ML/d is achieved, leaving an average shortfall of around 30 ML/d. This means that under climate change there is a decrease in compliance with low flow recommendations and an increase in the volume of water that will need to be released from storages in order to meet low flow recommendations.

Under the worst case scenario (2065_dry), a significant volume of water would need to be released just in order to meet the low flow recommendations; in many years the shortfall volume required to meet low flow recommendations would actually exceed the total volume presently held in the Environmental Water Entitlement.

The analysis also shows that there is relatively little difference in shortfalls when comparing current and 2040_med climate outlook conditions. This means that for the next 10-20 years the management of the environmental water reserve can be undertaken in a similar way regardless of the climate outlook (assuming an extended drought does not occur). However, after that period, it will become increasingly difficult to meet the current level of compliance using the existing volume of environmental entitlement. Moreover, it is important to use the time available in the next 10 years to develop a more comprehensive plan for when climate change starts to manifest in a more significant way (likely to be from ~2030 onwards).

Shortfall volumes have not been calculated for fresh and high flow events, but the significant reduction in compliance with these events under climate change indicates that the ability to deliver these events in the future will become increasingly difficult. This has significant consequences for values reliant on high flows for certain life history requirements.

Table 19 : Compliance with environmental flow recommendations under current and climate change scenarios for Reach 2 in the Tarago River.

Current

Climate year type	Year	Summer low	Winter low	Summer Fresh	Winter Fresh	Summer High	Winter High	Bankfull (Interval between events)	Overbank (Interval between events)
dry	1981	0.45	0.23	0.00	0.67	1.00	0.00	0	1
dry	1982	0.80	0.09	0.00	0.00	0.00	0.00	1	2
dry	1983	0.76	0.20	0.00	0.67	0.00	1.00	0	3
wet	1984	0.80	0.41	0.00	1.00	1.00	1.00	0	0
wet	1985	0.95	0.44	0.00	0.67	0.00	0.00	1	1
wet	1986	0.85	0.52	0.40	0.67	1.00	1.00	0	0
dry	1987	0.83	0.23	0.20	0.00	0.00	0.00	0	1
dry	1988	0.89	0.05	0.00	0.33	0.00	0.00	0	2
avg.	1989	0.98	0.43	0.20	0.33	0.00	1.00	0	0
avg.	1990	0.85	0.31	0.20	0.67	1.00	0.00	0	0
wet	1991	0.79	0.51	0.00	1.00	0.00	0.00	0	0
wet	1992	1.00	0.71	0.60	0.33	1.00	1.00	0	0
wet	1993	0.99	0.53	0.20	1.00	0.00	1.00	0	0
avg.	1994	0.99	0.37	0.20	0.00	0.00	0.00	0	1
wet	1995	0.99	0.79	0.40	1.00	1.00	1.00	0	0
wet	1996	1.00	0.52	0.80	0.67	1.00	1.00	0	0
dry	1997	0.99	0.10	0.00	0.00	0.00	0.00	1	1
avg.	1998	0.99	0.27	0.00	0.00	1.00	0.00	2	2
avg.	1999	0.99	0.12	0.20	0.33	1.00	0.00	3	3
avg.	2000	1.00	0.39	0.00	0.67	1.00	0.00	4	4
avg.	2001	0.99	0.30	0.20	0.33	1.00	0.00	5	5
dry	2002	0.99	0.07	0.20	0.00	1.00	0.00	6	6
dry	2003	0.84	0.21	0.00	0.33	0.00	1.00	0	7
wet	2004	1.00	0.60	0.20	0.67	1.00	1.00	0	8
avg.	2005	0.99	0.12	0.20	0.00	0.00	0.00	0	9
dry	2006	0.99	0.01	0.00	0.00	0.00	0.00	1	10
dry	2007	0.92	0.03	0.20	0.00	0.00	0.00	2	11
dry	2008	0.93	0.07	0.20	0.00	0.00	0.00	3	12
dry	2009	0.73	0.14	0.20	0.67	0.00	1.00	0	0
avg.	2010	0.89	0.36	0.00	1.00	0.00	1.00	0	0
wet	2011	0.99	0.86	0.80	1.00	1.00	1.00	0	0
wet	2012	1.00	0.82	0.60	1.00	1.00	0.00	0	0
avg.	2013	0.90	0.52	0.20	1.00	1.00	1.00	1	1
wet	2014	0.99	0.60	0.40	0.67	1.00	0.00	0	2
avg.	2015	0.99	0.35	0.40	0.67	1.00	0.00	0	0
avg.	2016	0.95	0.34	0.20	0.00	1.00	0.00	1	1

2040_med

Climate year type	Year	Summer low	Winter low	Summer Fresh	Winter Fresh	Summer High	Winter High	Bankfull (Interval between events)	Overbank (Interval between events)
dry	1981	0.67	0.18	0.00	0.33	1.00	0.00	0	1
dry	1982	0.74	0.07	0.00	0.00	0.00	0.00	1	2
dry	1983	0.73	0.19	0.00	0.67	0.00	1.00	0	3
wet	1984	0.73	0.38	0.00	0.67	1.00	1.00	0	0
wet	1985	0.89	0.40	0.00	0.67	0.00	0.00	1	1
wet	1986	0.78	0.48	0.40	0.67	1.00	1.00	0	2
dry	1987	0.79	0.18	0.20	0.00	0.00	0.00	0	3
dry	1988	0.86	0.04	0.00	0.00	0.00	0.00	0	4
avg.	1989	0.97	0.32	0.20	0.33	0.00	1.00	0	0
avg.	1990	0.77	0.25	0.00	0.67	1.00	0.00	0	0
wet	1991	0.65	0.45	0.00	0.67	0.00	0.00	0	1
wet	1992	1.00	0.63	0.60	0.33	1.00	1.00	0	0
wet	1993	0.99	0.51	0.40	1.00	0.00	1.00	0	0
avg.	1994	0.99	0.27	0.20	0.00	0.00	0.00	1	1
wet	1995	0.99	0.74	0.40	1.00	1.00	0.00	0	2
wet	1996	1.00	0.47	0.60	0.67	1.00	1.00	0	0
dry	1997	0.99	0.06	0.00	0.00	0.00	0.00	1	1
avg.	1998	0.99	0.23	0.00	0.00	1.00	0.00	2	2
avg.	1999	0.99	0.09	0.00	0.00	1.00	0.00	3	3
avg.	2000	1.00	0.29	0.00	0.33	1.00	0.00	4	4
avg.	2001	0.99	0.25	0.20	0.33	1.00	0.00	5	5
dry	2002	0.99	0.05	0.00	0.00	1.00	0.00	6	6
dry	2003	0.84	0.18	0.00	0.33	0.00	1.00	7	7
wet	2004	1.00	0.49	0.00	0.67	1.00	1.00	0	8
avg.	2005	0.99	0.09	0.20	0.00	0.00	0.00	0	9
dry	2006	0.99	0.01	0.00	0.00	0.00	0.00	1	10
dry	2007	0.90	0.02	0.20	0.00	0.00	0.00	2	11
dry	2008	0.85	0.06	0.00	0.00	0.00	0.00	3	12
dry	2009	0.70	0.13	0.00	0.67	0.00	1.00	0	0
avg.	2010	0.84	0.34	0.00	1.00	0.00	1.00	0	1
wet	2011	0.99	0.80	1.00	1.00	1.00	1.00	0	0
wet	2012	1.00	0.81	0.80	1.00	1.00	0.00	0	0
avg.	2013	0.84	0.47	0.20	0.67	1.00	0.00	1	1
wet	2014	0.94	0.53	0.40	0.67	1.00	0.00	2	2
avg.	2015	0.99	0.30	0.20	0.67	1.00	0.00	0	3
avg.	2016	0.91	0.26	0.00	0.00	1.00	0.00	1	4

2040_dry

Climate year type	Year	Summer low	Winter low	Summer Fresh	Winter Fresh	Summer High	Winter High	Bankfull (Interval between events)	Overbank (Interval between events)
dry	1981	0.58	0.14	0.00	0.33	0.00	0.00	1	1
dry	1982	0.63	0.04	0.00	0.00	0.00	0.00	2	2
dry	1983	0.58	0.13	0.00	0.00	0.00	0.00	0	3
wet	1984	0.55	0.35	0.00	0.67	1.00	1.00	0	0
wet	1985	0.67	0.32	0.00	0.00	0.00	0.00	1	1
wet	1986	0.72	0.42	0.60	1.00	1.00	1.00	0	2
dry	1987	0.67	0.14	0.20	0.00	0.00	0.00	1	3
dry	1988	0.74	0.03	0.00	0.00	0.00	0.00	0	4
avg.	1989	0.83	0.24	0.00	0.33	0.00	1.00	0	5
avg.	1990	0.64	0.20	0.00	0.33	1.00	0.00	0	0
wet	1991	0.46	0.34	0.00	0.67	0.00	0.00	0	1
wet	1992	0.96	0.46	0.40	0.67	0.00	1.00	0	2
wet	1993	0.96	0.47	0.20	0.67	0.00	1.00	0	0
avg.	1994	0.99	0.17	0.20	0.00	0.00	0.00	1	1
wet	1995	0.99	0.64	0.20	0.67	1.00	0.00	0	2
wet	1996	1.00	0.38	0.20	0.67	1.00	0.00	0	0
dry	1997	0.99	0.04	0.00	0.00	0.00	0.00	1	1
avg.	1998	0.99	0.14	0.00	0.00	1.00	0.00	2	2
avg.	1999	0.99	0.05	0.00	0.00	1.00	0.00	3	3
avg.	2000	0.99	0.21	0.00	0.33	1.00	0.00	4	4
avg.	2001	0.99	0.15	0.20	0.00	1.00	0.00	5	5
dry	2002	0.99	0.02	0.00	0.00	1.00	0.00	6	6
dry	2003	0.81	0.16	0.00	0.00	0.00	0.00	7	7
wet	2004	1.00	0.29	0.00	0.33	1.00	0.00	8	8
avg.	2005	0.99	0.07	0.20	0.00	0.00	0.00	9	9
dry	2006	0.99	0.00	0.00	0.00	0.00	0.00	10	10
dry	2007	0.82	0.01	0.20	0.00	0.00	0.00	11	11
dry	2008	0.70	0.03	0.00	0.00	0.00	0.00	12	12
dry	2009	0.63	0.10	0.00	0.67	0.00	1.00	0	0
avg.	2010	0.69	0.29	0.00	0.67	0.00	1.00	0	1
wet	2011	0.99	0.65	0.80	0.67	1.00	1.00	0	0
wet	2012	1.00	0.74	1.00	1.00	1.00	0.00	0	1
avg.	2013	0.64	0.34	0.20	0.00	0.00	0.00	1	2
wet	2014	0.79	0.35	0.00	0.33	0.00	0.00	2	3
avg.	2015	0.75	0.19	0.00	0.67	0.00	0.00	0	4
avg.	2016	0.87	0.18	0.00	0.00	0.00	0.00	1	5

2065_med

Climate year type	Year	Summer low	Winter low	Summer Fresh	Winter Fresh	Summer High	Winter High	Bankfull (Interval between events)	Overbank (Interval between events)
dry	1981	0.65	0.16	0.00	0.33	1.00	0.00	0	1
dry	1982	0.72	0.07	0.00	0.00	0.00	0.00	1	2
dry	1983	0.69	0.15	0.00	0.67	0.00	1.00	0	3
wet	1984	0.67	0.37	0.00	0.67	1.00	1.00	0	0
wet	1985	0.86	0.39	0.00	0.33	0.00	0.00	1	1
wet	1986	0.75	0.47	0.60	1.00	1.00	1.00	0	2
dry	1987	0.75	0.18	0.20	0.00	0.00	0.00	0	3
dry	1988	0.84	0.03	0.00	0.00	0.00	0.00	0	4
avg.	1989	0.93	0.30	0.20	0.33	0.00	1.00	0	0
avg.	1990	0.73	0.24	0.00	0.67	1.00	0.00	0	0
wet	1991	0.60	0.43	0.00	0.67	0.00	0.00	0	1
wet	1992	0.99	0.55	0.60	0.33	1.00	1.00	0	2
wet	1993	0.99	0.49	0.40	1.00	0.00	1.00	0	0
avg.	1994	0.99	0.24	0.20	0.00	0.00	0.00	1	1
wet	1995	0.99	0.72	0.40	1.00	1.00	0.00	0	2
wet	1996	1.00	0.43	0.60	0.67	1.00	1.00	0	0
dry	1997	0.99	0.05	0.00	0.00	0.00	0.00	1	1
avg.	1998	0.99	0.20	0.00	0.00	1.00	0.00	2	2
avg.	1999	0.99	0.08	0.00	0.00	1.00	0.00	3	3
avg.	2000	1.00	0.26	0.00	0.33	1.00	0.00	4	4
avg.	2001	0.99	0.21	0.20	0.00	1.00	0.00	5	5
dry	2002	0.99	0.04	0.00	0.00	1.00	0.00	6	6
dry	2003	0.81	0.17	0.00	0.33	0.00	1.00	7	7
wet	2004	1.00	0.41	0.00	0.67	1.00	1.00	0	8
avg.	2005	0.99	0.09	0.20	0.00	0.00	0.00	0	9
dry	2006	0.99	0.00	0.00	0.00	0.00	0.00	1	10
dry	2007	0.89	0.02	0.20	0.00	0.00	0.00	2	11
dry	2008	0.83	0.05	0.00	0.00	0.00	0.00	3	12
dry	2009	0.69	0.12	0.00	0.67	0.00	1.00	0	0
avg.	2010	0.80	0.32	0.00	1.00	0.00	1.00	0	1
wet	2011	0.99	0.77	1.00	1.00	1.00	1.00	0	0
wet	2012	1.00	0.80	0.80	1.00	1.00	0.00	0	0
avg.	2013	0.74	0.42	0.20	0.67	1.00	0.00	1	1
wet	2014	0.93	0.46	0.20	0.67	0.00	0.00	2	2
avg.	2015	0.99	0.26	0.00	0.67	1.00	0.00	0	3
avg.	2016	0.90	0.24	0.00	0.00	0.00	0.00	1	4

2065_dry

Climate year type	Year	Summer low	Winter low	Summer Fresh	Winter Fresh	Summer High	Winter High	Bankfull (Interval between events)	Overbank (Interval between events)
dry	1981	0.51	0.11	0.00	0.33	0.00	0.00	1	1
dry	1982	0.47	0.03	0.00	0.00	0.00	0.00	2	2
dry	1983	0.48	0.10	0.00	0.00	0.00	0.00	3	3
wet	1984	0.32	0.28	0.00	0.33	1.00	0.00	0	4
wet	1985	0.49	0.24	0.00	0.00	0.00	0.00	1	5
wet	1986	0.58	0.31	0.20	0.67	1.00	0.00	0	6
dry	1987	0.49	0.06	0.20	0.00	0.00	0.00	1	7
dry	1988	0.55	0.03	0.00	0.00	0.00	0.00	2	8
avg.	1989	0.63	0.14	0.00	0.33	0.00	1.00	0	9
avg.	1990	0.50	0.12	0.00	0.00	0.00	0.00	0	10
wet	1991	0.38	0.26	0.00	0.33	0.00	0.00	1	11
wet	1992	0.93	0.36	0.40	0.67	0.00	1.00	0	12
wet	1993	0.93	0.38	0.20	0.33	0.00	0.00	0	13
avg.	1994	0.99	0.10	0.20	0.00	0.00	0.00	1	14
wet	1995	0.99	0.46	0.00	0.33	1.00	0.00	2	15
wet	1996	1.00	0.30	0.20	0.33	1.00	0.00	0	0
dry	1997	0.99	0.02	0.00	0.00	0.00	0.00	1	1
avg.	1998	0.99	0.10	0.00	0.00	0.00	0.00	2	2
avg.	1999	0.99	0.04	0.00	0.00	0.00	0.00	3	3
avg.	2000	0.93	0.15	0.00	0.00	1.00	0.00	4	4
avg.	2001	0.99	0.08	0.00	0.00	1.00	0.00	5	5
dry	2002	0.99	0.01	0.00	0.00	0.00	0.00	6	6
dry	2003	0.78	0.10	0.00	0.00	0.00	0.00	7	7
wet	2004	1.00	0.19	0.00	0.00	0.00	0.00	8	8
avg.	2005	0.99	0.05	0.20	0.00	0.00	0.00	9	9
dry	2006	0.98	0.00	0.00	0.00	0.00	0.00	10	10
dry	2007	0.69	0.01	0.00	0.00	0.00	0.00	11	11
dry	2008	0.65	0.02	0.00	0.00	0.00	0.00	12	12
dry	2009	0.62	0.08	0.00	0.67	0.00	0.00	0	0
avg.	2010	0.54	0.23	0.00	0.67	0.00	0.00	1	1
wet	2011	0.97	0.49	0.80	0.33	1.00	0.00	0	0
wet	2012	1.00	0.54	1.00	0.00	1.00	0.00	0	1
avg.	2013	0.49	0.24	0.00	0.00	0.00	0.00	1	2
wet	2014	0.62	0.24	0.00	0.00	0.00	0.00	2	3
avg.	2015	0.66	0.13	0.00	0.33	0.00	0.00	3	4
avg.	2016	0.76	0.10	0.00	0.00	0.00	0.00	4	5

Compliance Categories

Mostly complies	Greater than	95 %		of time / years
Frequently complies	Between	76 &	95 %	of time / years
Often complies	Between	51 &	75 %	of time / years
Occasionally complies	Between	26 &	50 %	of time / years
Rarely complies	Between	5 &	25 %	of time / years
Never complies	Between	0 &	5 %	of time / years

Table 20 : Compliance with environmental flow recommendations under current and climate change scenarios for Reach 6 in the Bunyip River.

		Current							2040_med						
Climate year type	Year	Summer low	Winter low	Summer Fresh	Winter Fresh	Summer High	Winter High	Bankfull (Interval between events)	Summer low	Winter low	Summer Fresh	Winter Fresh	Summer High	Winter High	Bankfull (Interval between events)
avg.	1981	0.63	1.00	0.00	1.00	1.00	1.00	0	0.51	0.98	0.00	1.00	1.00	1.00	0
dry	1982	0.69	0.84	0.00	1.00	0.00	0.00	1	0.54	0.79	0.00	1.00	0.00	0.00	1
dry	1983	0.36	1.00	0.00	1.00	0.00	1.00	0	0.21	0.99	0.00	1.00	0.00	1.00	0
wet	1984	0.58	1.00	0.33	1.00	1.00	1.00	0	0.45	0.99	0.33	1.00	1.00	1.00	0
avg.	1985	0.51	1.00	0.33	1.00	1.00	1.00	0	0.38	1.00	0.33	1.00	0.00	1.00	0
wet	1986	0.67	1.00	0.67	1.00	1.00	1.00	0	0.62	1.00	0.67	1.00	1.00	1.00	0
avg.	1987	0.86	0.99	1.00	1.00	1.00	1.00	0	0.73	0.95	1.00	1.00	1.00	1.00	0
dry	1988	0.45	0.90	0.33	1.00	0.00	1.00	0	0.37	0.89	0.33	1.00	0.00	1.00	0
wet	1989	0.78	1.00	0.67	0.50	0.00	1.00	0	0.70	1.00	0.67	0.50	0.00	1.00	0
avg.	1990	0.79	1.00	0.33	1.00	1.00	1.00	0	0.66	1.00	0.33	1.00	1.00	1.00	0
wet	1991	0.67	0.98	0.00	0.50	0.00	1.00	0	0.41	0.97	0.00	0.50	0.00	1.00	0
wet	1992	1.00	1.00	1.00	0.50	1.00	1.00	0	1.00	1.00	0.67	0.50	1.00	1.00	0
wet	1993	0.99	1.00	0.33	0.50	1.00	1.00	0	0.99	1.00	0.33	0.50	1.00	1.00	0
wet	1994	0.99	1.00	0.33	0.50	1.00	1.00	0	0.99	1.00	0.33	1.00	1.00	1.00	0
wet	1995	0.99	1.00	0.67	0.50	1.00	1.00	0	0.99	1.00	1.00	0.50	1.00	1.00	0
wet	1996	1.00	1.00	0.33	0.50	1.00	1.00	0	1.00	1.00	0.33	0.50	1.00	1.00	0
avg.	1997	0.99	1.00	0.33	1.00	1.00	1.00	1	0.99	1.00	0.67	1.00	1.00	1.00	1
avg.	1998	0.99	1.00	0.33	1.00	1.00	1.00	2	0.99	1.00	0.33	1.00	1.00	1.00	2
avg.	1999	0.99	1.00	1.00	1.00	1.00	1.00	0	0.99	1.00	1.00	1.00	1.00	1.00	0
avg.	2000	0.99	1.00	0.67	0.50	1.00	1.00	0	0.99	1.00	0.33	1.00	1.00	1.00	0
avg.	2001	0.97	1.00	1.00	1.00	1.00	1.00	0	0.97	1.00	0.67	1.00	1.00	1.00	1
dry	2002	0.99	0.89	1.00	1.00	1.00	0.00	1	0.99	0.88	1.00	1.00	1.00	0.00	2
dry	2003	0.76	0.93	0.00	1.00	0.00	1.00	0	0.53	0.88	0.00	1.00	0.00	1.00	0
wet	2004	1.00	1.00	0.67	0.50	1.00	1.00	0	0.99	1.00	0.67	1.00	1.00	1.00	0
avg.	2005	0.99	1.00	1.00	1.00	0.00	1.00	0	0.99	1.00	0.67	1.00	0.00	1.00	0
dry	2006	0.99	0.73	1.00	1.00	1.00	0.00	1	0.96	0.70	0.67	1.00	1.00	0.00	1
dry	2007	0.74	0.67	0.00	1.00	0.00	0.00	2	0.58	0.57	0.00	1.00	0.00	0.00	2
dry	2008	0.74	0.73	0.67	1.00	0.00	0.00	3	0.69	0.69	1.00	1.00	0.00	0.00	3
dry	2009	0.65	0.88	0.33	1.00	0.00	1.00	0	0.47	0.84	0.33	1.00	0.00	1.00	0
dry	2010	0.50	1.00	0.00	1.00	0.00	1.00	0	0.43	1.00	0.00	1.00	0.00	1.00	0
wet	2011	0.99	1.00	0.33	0.50	1.00	1.00	0	0.99	1.00	0.33	0.50	1.00	1.00	0
wet	2012	1.00	1.00	0.33	1.00	1.00	1.00	0	1.00	1.00	0.67	1.00	1.00	1.00	0
avg.	2013	0.84	1.00	1.00	1.00	1.00	1.00	0	0.74	1.00	1.00	1.00	1.00	1.00	1
avg.	2014	0.98	1.00	1.00	1.00	1.00	1.00	0	0.88	1.00	0.67	1.00	1.00	1.00	2
dry	2015	0.97	0.96	1.00	1.00	1.00	0.00	0	0.94	0.93	1.00	1.00	1.00	0.00	0
dry	2016	0.89	1.00	0.33	1.00	0.00	1.00	0	0.77	1.00	0.00	1.00	0.00	1.00	0

		2040_dry							2065_med						
Climate year type	Year	Summer low	Winter low	Summer Fresh	Winter Fresh	Summer High	Winter High	Bankfull (Interval between events)	Summer low	Winter low	Summer Fresh	Winter Fresh	Summer High	Winter High	Bankfull (Interval between events)
avg.	1981	0.29	0.95	0.00	1.00	1.00	1.00	0	0.46	0.97	0.00	1.00	1.00	1.00	0
dry	1982	0.27	0.70	0.00	1.00	0.00	0.00	1	0.44	0.77	0.00	1.00	0.00	0.00	1
dry	1983	0.09	0.94	0.00	1.00	0.00	1.00	0	0.15	0.99	0.00	1.00	0.00	1.00	0
wet	1984	0.29	0.94	0.33	1.00	1.00	1.00	0	0.41	0.98	0.33	1.00	1.00	1.00	0
avg.	1985	0.26	1.00	0.00	1.00	0.00	1.00	0	0.33	1.00	0.33	1.00	0.00	1.00	0
wet	1986	0.51	0.98	0.67	1.00	1.00	1.00	0	0.59	1.00	0.67	1.00	1.00	1.00	0
avg.	1987	0.54	0.90	0.67	1.00	1.00	1.00	0	0.67	0.93	0.67	1.00	1.00	1.00	0
dry	1988	0.25	0.84	0.33	1.00	0.00	1.00	0	0.32	0.88	0.33	1.00	0.00	1.00	0
wet	1989	0.53	1.00	0.67	0.50	0.00	1.00	0	0.64	1.00	0.67	0.50	0.00	1.00	0
avg.	1990	0.36	0.99	0.33	1.00	1.00	1.00	0	0.57	1.00	0.33	1.00	1.00	1.00	0
wet	1991	0.24	0.95	0.00	1.00	0.00	1.00	0	0.36	0.96	0.00	1.00	0.00	1.00	0
wet	1992	0.99	1.00	0.67	1.00	1.00	1.00	0	1.00	1.00	0.67	1.00	1.00	1.00	0
wet	1993	0.99	1.00	0.33	1.00	0.00	1.00	0	0.99	1.00	0.33	1.00	0.00	1.00	0
wet	1994	0.99	1.00	0.33	1.00	1.00	1.00	0	0.99	1.00	0.33	1.00	1.00	1.00	0
wet	1995	0.99	1.00	0.67	0.50	1.00	1.00	0	0.99	1.00	1.00	0.50	1.00	1.00	0
wet	1996	1.00	1.00	0.33	0.50	1.00	1.00	0	1.00	1.00	0.33	0.50	1.00	1.00	0
avg.	1997	0.99	1.00	0.67	1.00	0.00	1.00	1	0.99	1.00	0.67	1.00	1.00	1.00	1
avg.	1998	0.98	1.00	0.33	1.00	1.00	1.00	2	0.99	1.00	0.33	1.00	1.00	1.00	2
avg.	1999	0.99	1.00	1.00	1.00	1.00	1.00	3	0.99	1.00	1.00	1.00	1.00	1.00	0
avg.	2000	0.97	1.00	0.33	1.00	1.00	1.00	4	0.98	1.00	0.33	1.00	1.00	1.00	1
avg.	2001	0.90	1.00	0.67	1.00	1.00	1.00	5	0.96	1.00	0.67	1.00	1.00	1.00	2
dry	2002	0.99	0.84	1.00	1.00	1.00	0.00	6	0.99	0.86	1.00	1.00	1.00	0.00	3
dry	2003	0.22	0.76	0.00	1.00	0.00	1.00	0	0.42	0.84	0.00	1.00	0.00	1.00	0
wet	2004	0.71	1.00	0.33	1.00	1.00	1.00	0	0.91	1.00	0.67	1.00	1.00	1.00	0
avg.	2005	0.99	1.00	0.67	1.00	0.00	1.00	0	0.99	1.00	0.67	1.00	0.00	1.00	0
dry	2006	0.86	0.61	0.00	0.50	0.00	0.00	1	0.96	0.67	0.67	0.50	1.00	0.00	1
dry	2007	0.13	0.46	0.00	1.00	0.00	0.00	2	0.44	0.54	0.00	1.00	0.00	0.00	2
dry	2008	0.65	0.57	0.33	0.50	0.00	0.00	3	0.68	0.67	1.00	1.00	0.00	0.00	3
dry	2009	0.17	0.71	0.33	1.00	0.00	1.00	0	0.40	0.81	0.33	1.00	0.00	1.00	0
dry	2010	0.26	0.98	0.00	1.00	0.00	1.00	0	0.37	1.00	0.00	1.00	0.00	1.00	0
wet	2011	0.99	1.00	0.33	0.50	1.00	1.00	0	0.99	1.00	0.33	0.50	1.00	1.00	0
wet	2012	1.00	1.00	1.00	0.50	1.00	1.00	0	1.00	1.00	0.67	1.00	1.00	1.00	0
avg.	2013	0.60	1.00	0.67	1.00	0.00	1.00	1	0.71	1.00	0.67	1.00	0.00	1.00	1
avg.	2014	0.73	0.98	0.33	1.00	0.00	1.00	2	0.84	1.00	0.33	1.00	1.00	1.00	2
dry	2015	0.84	0.87	0.33	0.50	1.00	0.00	0	0.92	0.92	1.00	0.50	1.00	0.00	0
dry	2016	0.47	1.00	0.00	1.00	0.00	1.00	1	0.67	1.00	0.00	1.00	0.00	1.00	0

		2065_dry						
Climate year type	Year	Summer low	Winter low	Summer Fresh	Winter Fresh	Summer High	Winter High	Bankfull (Interval between events)
avg.	1981	0.16	0.86	0.00	1.00	1.00	0.00	0
dry	1982	0.15	0.50	0.00	1.00	0.00	0.00	1
dry	1983	0.04	0.83	0.00	1.00	0.00	1.00	0
wet	1984	0.18	0.87	0.33	1.00	1.00	1.00	0
avg.	1985	0.20	0.93	0.00	1.00	0.00	1.00	0
wet	1986	0.44	0.96	0.67	1.00	1.00	1.00	0
avg.	1987	0.44	0.84	0.33	1.00	1.00	0.00	0
dry	1988	0.17	0.80	0.00	1.00	0.00	1.00	0
wet	1989	0.39	0.98	0.67	1.00	0.00	1.00	0
avg.	1990	0.21	0.93	0.33	1.00	1.00	1.00	0
wet	1991	0.13	0.90	0.00	1.00	0.00	0.00	0
wet	1992	0.86	1.00	0.67	1.00	0.00	1.00	0
wet	1993	0.99	1.00	0.33	1.00	0.00	1.00	0
wet	1994	0.99	1.00	0.33	1.00	1.00	1.00	1
wet	1995	0.97	1.00	0.67	0.50	1.00	1.00	0
wet	1996	1.00	1.00	0.67	0.50	1.00	1.00	0
avg.	1997	0.99	0.91	0.33	1.00	0.00	0.00	1
avg.	1998	0.52	1.00	0.00	1.00	1.00	1.00	2
avg.	1999	0.93	0.96	1.00	1.00	1.00	1.00	3
avg.	2000	0.54	1.00	0.00	1.00	1.00	1.00	4
avg.	2001	0.67	0.99	0.33	1.00	1.00	1.00	5
dry	2002	0.98	0.74	0.00	1.00	0.00	0.00	6
dry	2003	0.08	0.73	0.00	1.00	0.00	1.00	0
wet	2004	0.49	1.00	0.00	1.00	0.00	1.00	0
avg.	2005	0.99	0.95	0.33	1.00	0.00	0.00	0
dry	2006	0.41	0.33	0.00	0.50	0.00	0.00	1
dry	2007	0.05	0.31	0.00	1.00	0.00	0.00	2
dry	2008	0.60	0.46	0.00	0.50	0.00	0.00	3
dry	2009	0.08	0.54	0.00	1.00	0.00	1.00	0
dry	2010	0.09	0.92	0.00	1.00	0.00	1.00	1
wet	2011	0.99	1.00	0.67	1.00	1.00	1.00	0
wet	2012	1.00	0.99	1.00	1.00	1.00	1.00	0
avg.	2013	0.44	1.00	0.00	1.00	0.00	1.00	1
avg.	2014	0.51	0.94	0.33	1.00	0.00	0.00	2
dry	2015	0.64	0.77	0.33	1.00	0.00	0.00	0
dry	2016	0.30	0.95	0.00	1.00	0.00	1.00	1

Compliance Categories

Mostly complies		Greater than	95 %			of time / years
Frequently complies		Between	76 &	95 %		of time / years
Often complies		Between	51 &	75 %		of time / years
Occasionally complies		Between	26 &	50 %		of time / years
Rarely complies		Between	5 &	25 %		of time / years
Never complies		Between	0 &	5 %		of time / years

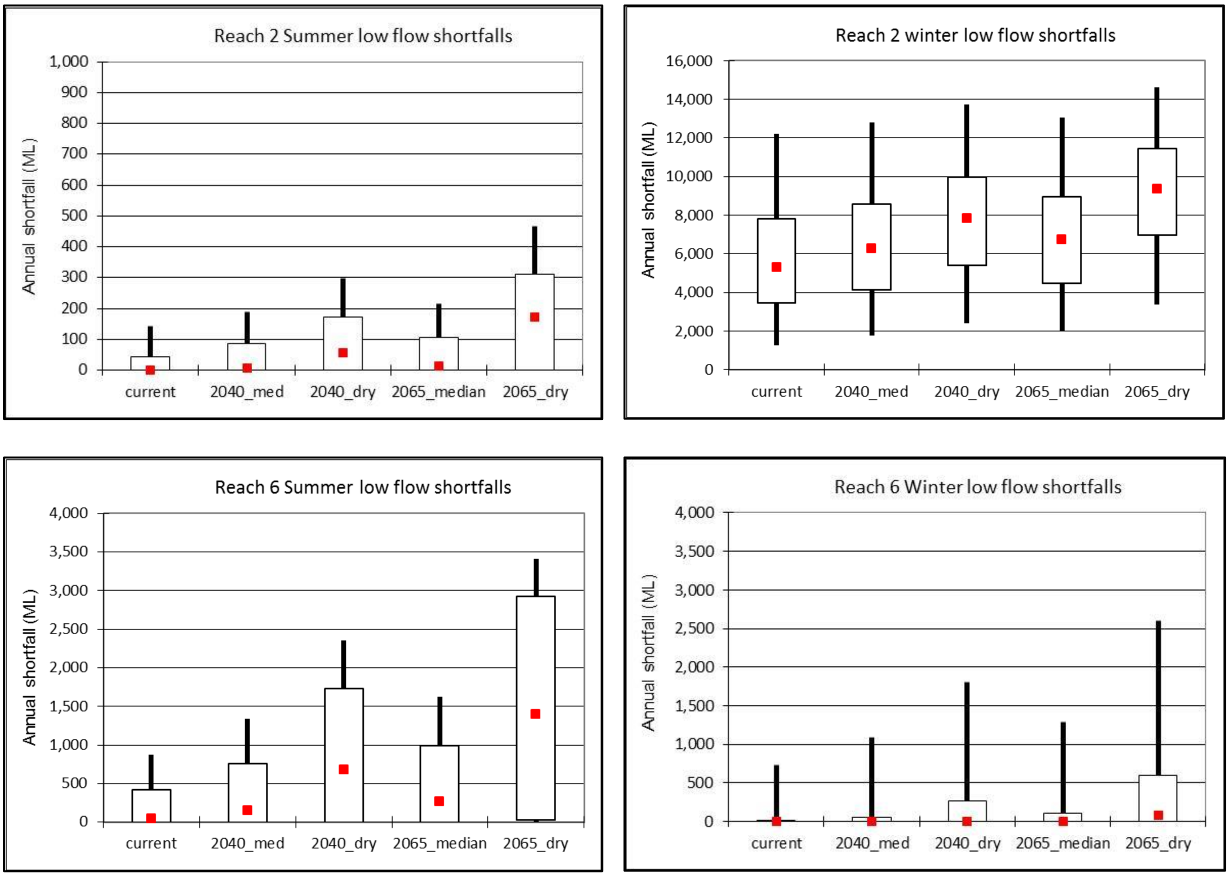


Figure 29 : Shortfall volumes required to achieve compliance with summer and winter low flow recommendations in reaches 2 and 6. The centre of the box marks the median annual shortfall volume, the margins of the box shows the 25th and 75th %ile shortfall volume ranges, and the whiskers mark the 5th and 95th %ile shortfall volume ranges.

13.2 Consequences for environmental values - Vulnerability

There are significant consequences of climate change for water dependant environmental values. In order to assess these consequences, the vulnerability of values was first determined and then an analysis completed to show how conditions for those values would change under future climate change flow scenarios. Vulnerability was based on life history requirements, sensitivity to environmental flow components and predicted ecological response to changes in flow components potentially impacted by climate change.

The types of ecological responses to climate change are likely to depend on the rate of change and the severity or magnitude of change (Figure 30). Responses can include; changes in behaviour, abundance, geographical range; adaptive micro- and macro-evolution; and under situations where there is a large and/or rapid change, extinction (Huntley et al. 2010).

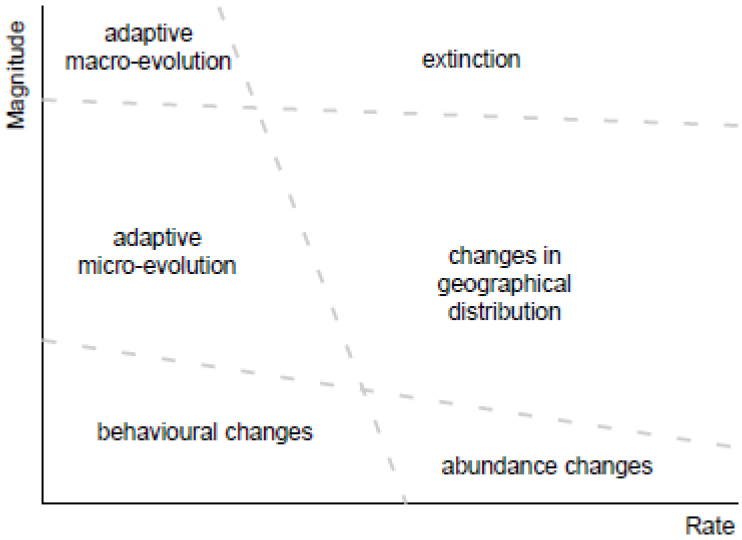


Figure 30 : Schematic representation of species' responses to climate change (from Huntley et al. 2010).

For this assessment, the above schematic has been adapted to show how water dependant species, functional groups (i.e. species with similar characteristics) or ecological processes are likely to respond to climate change. The predicted ecological responses are based on increasing severity of flow reduction (i.e. loss of high flow events, increasing duration of low flows and increasing frequency or duration of cease-to-flows) and the duration of impact (i.e. short term dry conditions, drought and longer term climate change).

13.2.1 Fish

Vulnerability plots for migratory fish and resident fish species are shown in Figure 31 and Figure 32. A reduction in bankfull and overbank flows is unlikely to result in a significant impact on riverine fish populations, but reductions in freshes and high flows that cue migration and spawning behaviours and an overall increase in the duration of low flows is likely to result in reduced abundance and a reduction in range in the short to medium term, and local extinction in the longer term. If severe drought and climate change results in the development of cease-to-flow conditions in otherwise perennial streams, or increases the frequency and duration of cease-to-flows in existing intermittent streams then localised extinction could occur more rapidly. Localised extinction of resident fish in the main Tarago / Bunyip River channel is unlikely *provided* low flows are maintained. However, the loss of migration and spawning cues could result in the local extinction of short-lived flow-sensitive species such as Australian Grayling.

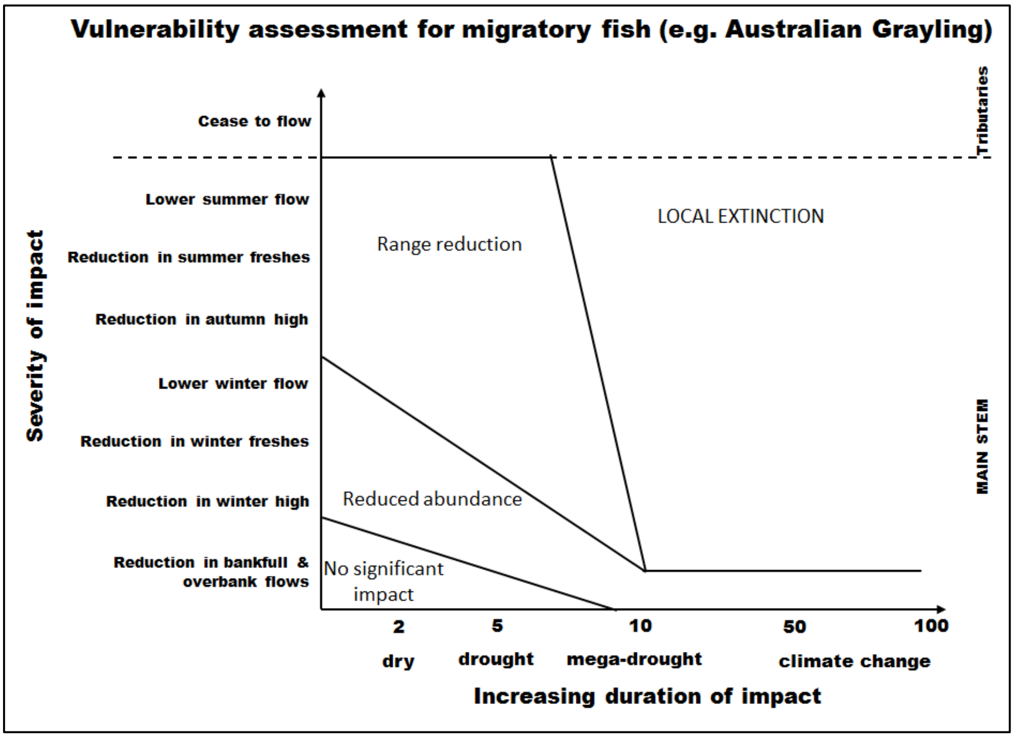


Figure 31 : Climate vulnerability assessment for flow sensitive migratory fish (e.g. Australian Grayling)

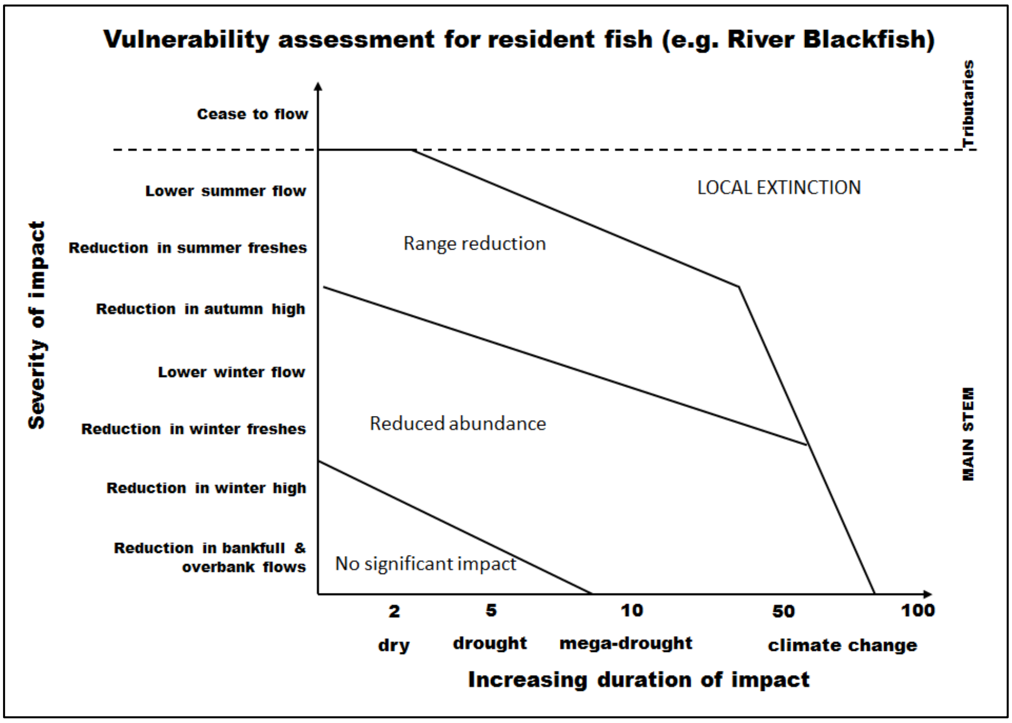


Figure 32 : Climate vulnerability assessment for resident fish (e.g. River Blackfish)

An analysis of predicted changes in fish distribution due to climate change shows that species such as River Blackfish and Australian Grayling could undergo significant range reductions; Short-finned Eel and some migratory galaxias species show relatively little predicted change in distribution; but exotic species, such as Common Carp and Red Fin Perch are predicted to expand their range (Bond *et al*. 2011). The authors indicate that temperature and shifts in flow regime towards increased durations of low flows and cease to flows are primary predictors in determining the likely fish response to climate change. An example of predicted range shift in River Blackfish is shown in Figure 33. Under climate change River Blackfish is predicted to become locally extinct in the west and north of the Divide and significantly contract in its range south of the Divide. It is predicted that the probability of detection of River Blackfish will significantly decline within the Bunyip / Tarago Catchment (Bond *et al.* 2011).

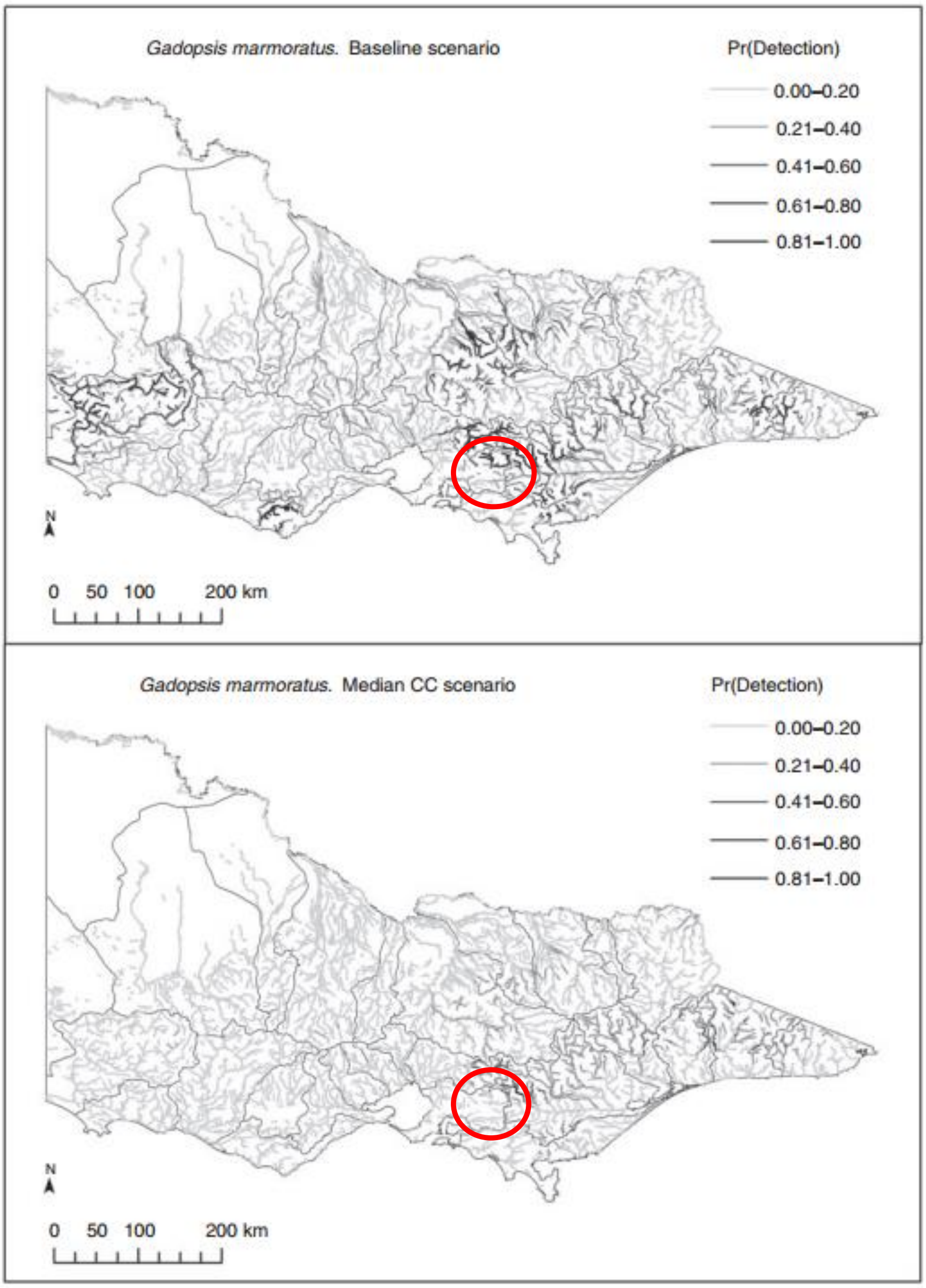


Figure 33 : Predicted historic (baseline) and median climate change-scenario prediction for River Blackfish distribution in Victoria (Bond et al. 2011). The red circle highlights the Bunyip / Tarago River catchment and shows the decline in probability of detection.

13.2.2 Platypus

Platypuses are reliant on the availability of permanent freshwater and riparian habitat; they feed exclusively on aquatic macrophytes and use burrows in stream banks for resting and nesting (Grant 2007). Despite a range of impacts on aquatic and riparian environments, platypuses still persist over much of their historical range (Grant and Temple-Smith 2003), including within the Melbourne area and the Bunyip / Tarago River catchment in particular. However, platypuses are likely to be highly vulnerable to climate change for a range of reasons. Factors contributing to their vulnerability include their dependence on adequate surface water for survival, their characteristically low population density and low reproductive rate, and the fact that female platypus are likely to be out-competed for food by larger (and more aggressive) males and therefore suffer disproportionately high mortality rates when surface water is severely limited (Serena and Williams 2010).

As a consequence, climate change impacts that result in increased duration of low flows and cease to flow events represent significant risks to platypus. Furthermore, warmer temperatures are also likely to represent a significant threat, with recent research suggesting the temperature increases since the 1960s have had a greater impact on platypus than aquatic habitat availability (Klamt *et al.* 2011). The combination of drier conditions and warmer temperatures are hence likely to have compounding effects on platypus through loss of aquatic habitat, reduction in availability of sufficient macroinvertebrate food resources and potential change in composition of food types, and changes to composition of riparian vegetation that may increase exposure of platypuses to higher temperatures. Impacts that result in platypus having to leave the water to travel between isolated pool habitats, or that reduce the amount of cover provided by riparian vegetation are also likely to result in higher levels of predation (Serena and Williams 2010).

Figure 34 summarises the broad response of platypus to drought and climate change induced impacts on stream flow. An increase in cease to flow and increased duration of low flows will over time lead to localised extinction. Increased low flows and a loss of freshes and high flows are likely to lead to reduced abundance and range reductions, mainly due to the impacts that the loss of these flow components will have on food production. In the short term a loss of high flows and overbank flows is unlikely to impact on platypus, but over time, the loss of these flow components will impact on riparian vegetation with consequent impacts on platypus through degradation of riparian habitat, increased exposure to higher temperatures and increased predation.

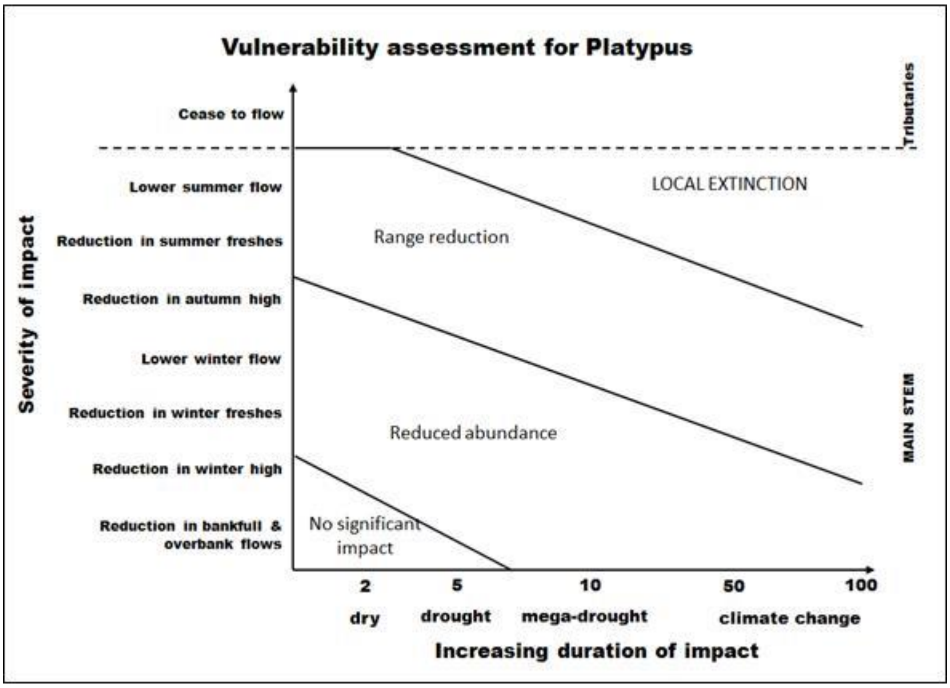


Figure 34 : Climate vulnerability assessment for platypus

13.2.3 Macroinvertebrates

The response of aquatic macroinvertebrates to climate change is likely to vary depending on flow and temperature tolerances and preferences (Chessman 2012). At a community composition level, climate change and the consequent drying and warming of aquatic ecosystems will lead to a shift in the composition of macroinvertebrates towards taxa that are tolerant of warmer and drier conditions (Chessman 2013) (Figure 35). This also means a loss of taxa that favour cooler and faster flowing conditions, such as many animals in the Ephemeroptera (mayflies), Plecoptera (stoneflies) and Trichoptera (caddisflies) orders (often referred to as EPT taxa) (Chessman 2009), which often form a major component of the diet of fish (Chessman 2013) and platypus (Grant 2007). Furthermore, within the Bunyip / Tarago catchment burrowing crayfish are a valued species. It is unclear how crayfish will respond to climate change, but changes in flow variability, groundwater levels and the drying of the riparian zone is likely to impact on habitat conditions for these species.

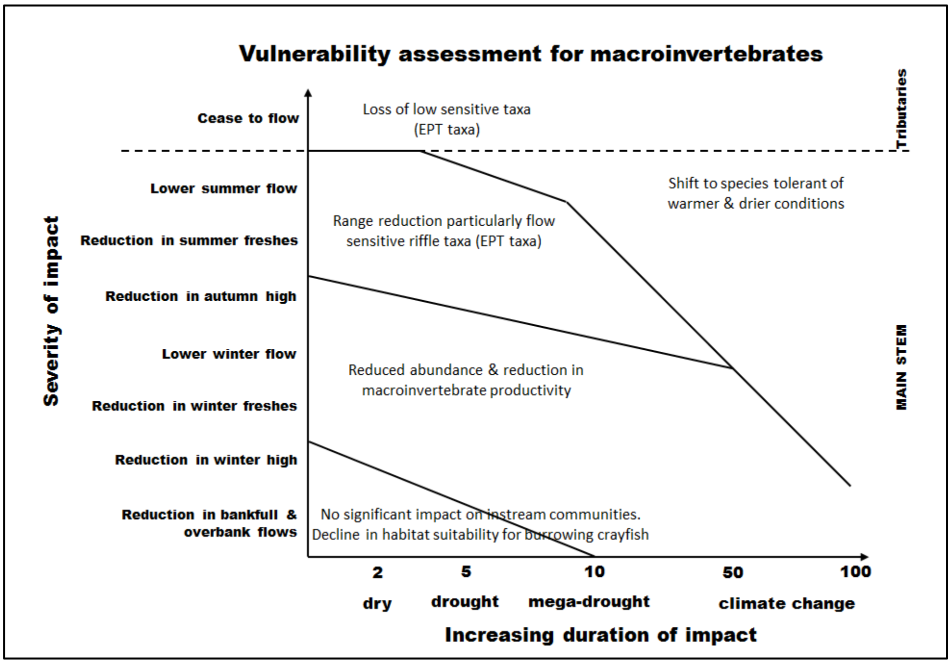


Figure 35 : Climate vulnerability assessment for macroinvertebrates

13.2.4 Frogs

As with the other species described above, climate change impacts on frog species will vary according to their water and temperature tolerances, and specific habitat and hydroperiod requirements (Carey and Alexander 2003). There are also a range of indirect impacts, including changes in food availability, disease, UV radiation and species-specific interactions (Blaustein *et al.* 2010)

Figure 36 provides a summary of the general impacts to frogs along the Bunyip / Tarago River in response to the possible flow regimes changes as a result of climate change. An overall drier flow regime is likely to lead to a range reduction and reduced abundance of species that favour within-channel habitats. However, the greater impacts are likely to be to species that prefer riparian and floodplain habitats. In these locations, a reduction in the frequency of bankfull and of overbank flows that also leads to a loss of wetland habitat and reduction in hydroperiod is likely to result in a reduction in range and in some areas a loss of species that require wetland inundation for breeding. This will particularly be the case if the interval between events that inundate wetlands is longer than the life span of the species in question.

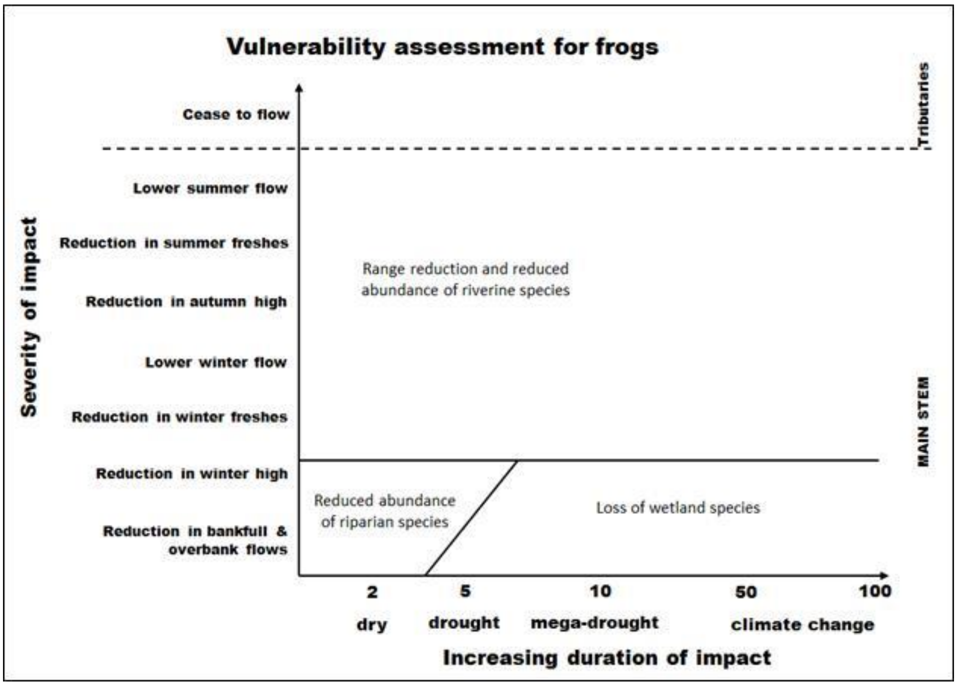


Figure 36 : Climate vulnerability assessment for frogs

13.2.5 Waterbirds

The vulnerability of waterbirds to climate change is likely to be highly variable depending on specific species tolerances and preferences and is most likely to be related to impacts on habitat types and water availability. Figure 37 summarises the possible end points for various waterbird functional groups based on how climate change may impact on the flow regime for the Tarago and Bunyip Rivers. An overall reduction in flow may result in a shift in species composition to opportunistic and invasive species. A reduction in the frequency of overbank flows is likely to result in reduced abundance of species that prefer wetland habitats.

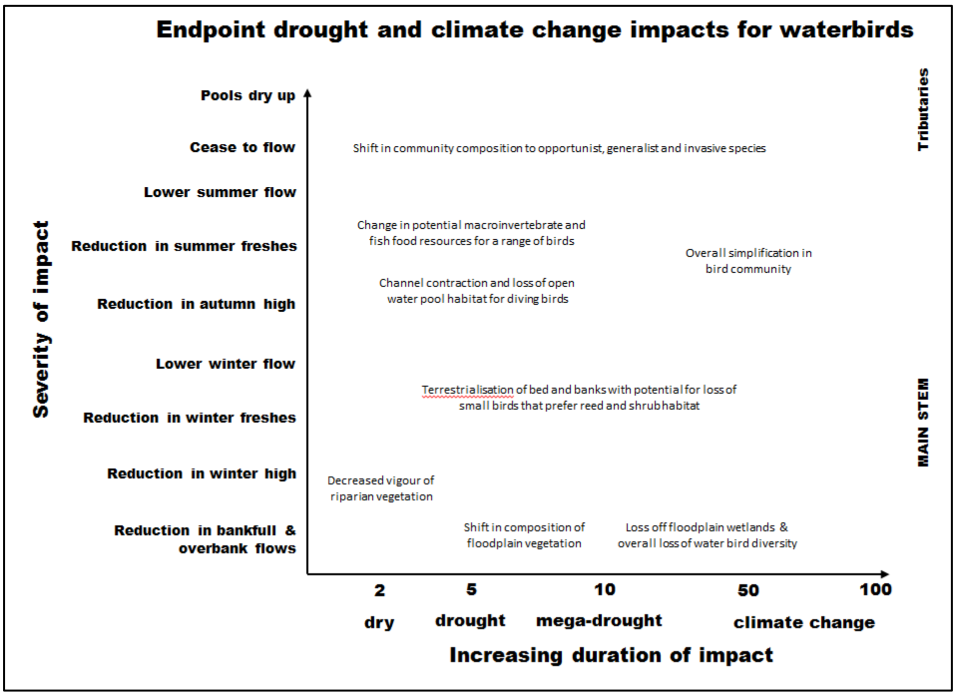


Figure 37 : Climate vulnerability assessment for waterbirds

13.2.6 Vegetation

Figure 38 summarises the potential endpoint responses of water-dependant vegetation to climate change induced changes in flow regime. Reduced in-channel flows and reduced frequency of bankfull and overbank flows means drier conditions in the riparian and floodplain zones, resulting in a shift towards vegetation communities that are more tolerant of dry conditions. Drier floodplains are also likely to result in the loss of some wetland types that will no longer hold water long enough to support water dependant plant communities (Nielsen and Brock 2009). A reduction in in-channel flows, and in particular an increase in the duration of low flows is likely to result in the terrestrialisation of the stream bank, and in severe cases the stream bed (e.g. in response to long durations of cease to flow). Growth of terrestrial vegetation within the channel can then pose significant risks when floods do occur because the vegetation is scoured from the channel and swept downstream, potentially increasing the severity of bed and bank erosion through physical abrasion.

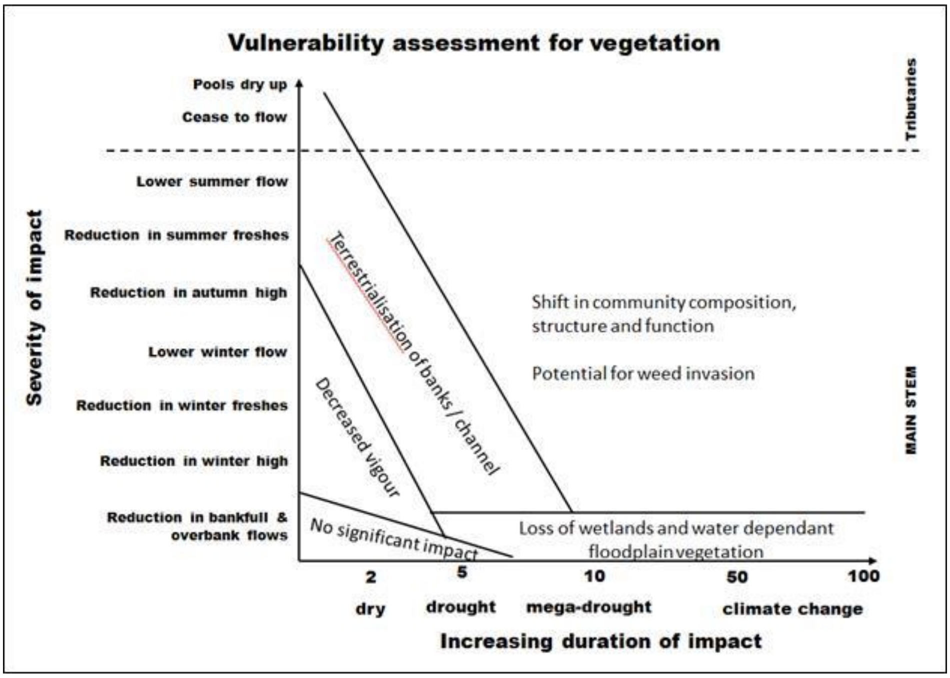


Figure 38 : Climate vulnerability assessment for vegetation

13.3 Summary of endpoint outcomes

Figure 39 shows a summary of predicted end points for the range of values assessed for the Bunyip / Tarago River under drought and climate change outlooks. A reduction in the frequency and duration of bankfull and overbank flows will ultimately lead to a reduction in the vigour of riparian and floodplain vegetation and result in a shift towards plants that are tolerant of drier and warmer conditions. Over the medium to long term there will also be a loss of existing wetland/billabong habitat. Over the longer term, the loss of bankfull and overbank flows could also have negative consequences for in-channel food webs because the loss of hydrological connectivity between the river and floodplain/wetlands interrupts the movement of nutrients and organic material that are important food resources for in-stream organisms. Reductions in bankfull flows and freshes will lead to further channel contraction and encroachment of terrestrial vegetation on the river banks. However, a potential increase in high intensity rainfall and flood events could cause significant scour and damage to the channel from time to time.

Within the channel, climate change impacts that result in a reduction in the frequency of fresh flows and an increase in the duration of low flows and cease to flows will over time result in the steady decline in abundance of flow sensitive taxa, including fish, macroinvertebrates, platypus and frogs. Some of these taxa could eventually become locally extinct. For species that are endangered or vulnerable on a regional and/or national basis, this may have serious implications for our ability to protect these species from total extinction.

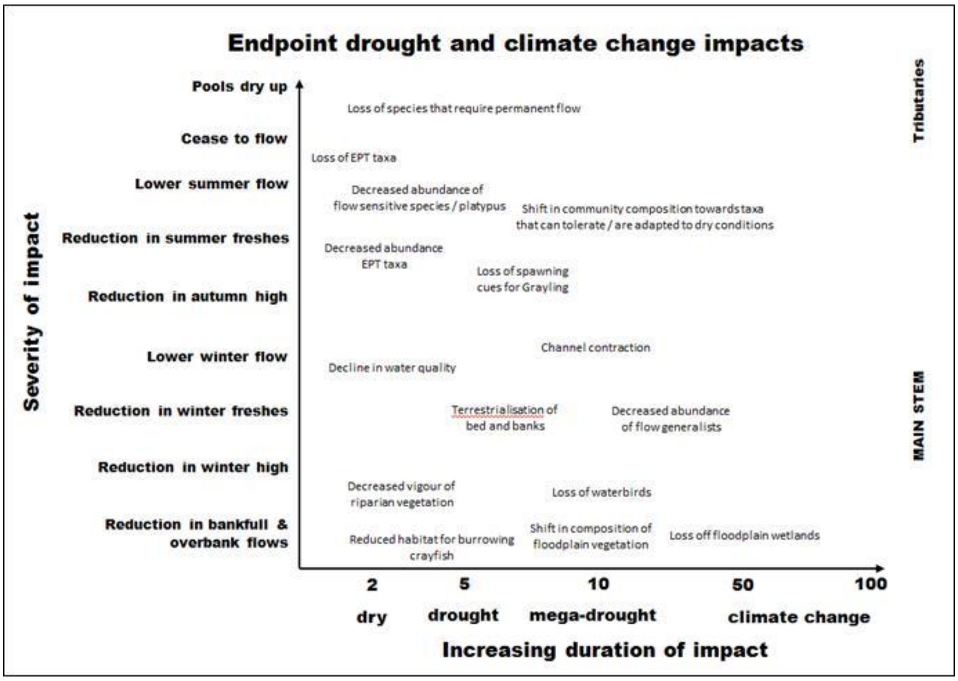


Figure 39 : Summary of endpoint drought and climate change outcomes for Tarago/Bunyip River values

13.4 Flow conditions under current and climate change scenarios

From the vulnerability plots, priority flow components were determined that would need to be delivered with a high degree of compliance in order to maintain the condition of the ecological value (let alone improve it). For example, resident fish sensitive to increased duration of low flows would need to experience a high degree of compliance with low flow recommendations in both summer and winter in order to maintain (or improve) their condition (under both current and climate change scenarios). If climate change results in a decrease in compliance with low flow recommendations, then the condition of the value would be expected to deteriorate. The priority of various flow components for each value is shown in Table 21.

Using the priorities in Table 21 and compliance assessment (see Section 13.1.1), a time series of condition could be developed that shows the overall flow condition in any one year based on the degree to which recommended flows were complied with and weighted towards relevant priority flows components. The condition score is scaled so that 1 indicates perfect conditions (i.e. all relevant flow components were complied with) and 0 indicates poor conditions (i.e. no relevant flow components were complied with). Time series of conditions score were determined for current flow conditions and under a range of climate change scenarios whereby the current flow was scaled downwards as described in Section 13.1. Using this approach it is possible to see how patterns in flow conditions for various values could be expected to change under various climate change scenarios.

Table 21 : Flow component priorities for Bunyip / Tarago River values. 0, not specifically required to support value; 1, low priority; 2, moderate priority; 3, high priority; 4, essential.

Value	Summer low flow	Summer fresh	Autumn high flow	Winter low flow	Winter fresh	Winter high flow	Bankfull	Overbank	Justification for prioritisation
Resident fish	4	4	1	4	2	1	0	0	Weighted for Low flows& freshes to maintain access to pool habitat and good water quality
Migratory fish	4	1	4	3	2	4	0	0	Weighted for high flows to trigger migration and spawning
Platypus	4	3	1	4	2	1	0	0	Weighted for Low flows& freshes to maintain access to pool habitat, good water quality and food resources
Macroinvertebrates	4	4	1	4	2	1	0	0	Weighted for Low flows& freshes to maintain access to pool habitat and good water quality
Frogs	2	1	1	2	1	1	3	4	Weighted for Low flows & overbank flow to maintain instream pool habitat and inundate wetlands
Birds	2	2	2	2	2	3	3	4	Weighted for Low flows & overbank flow to maintain in channel vegetation habitats and inundate wetlands
Vegetation	2	1	1	2	2	4	4	4	Weighted for high flows, bankfull & overbank flow to maintain soil moisture in banks and floodplain and inundate wetlands

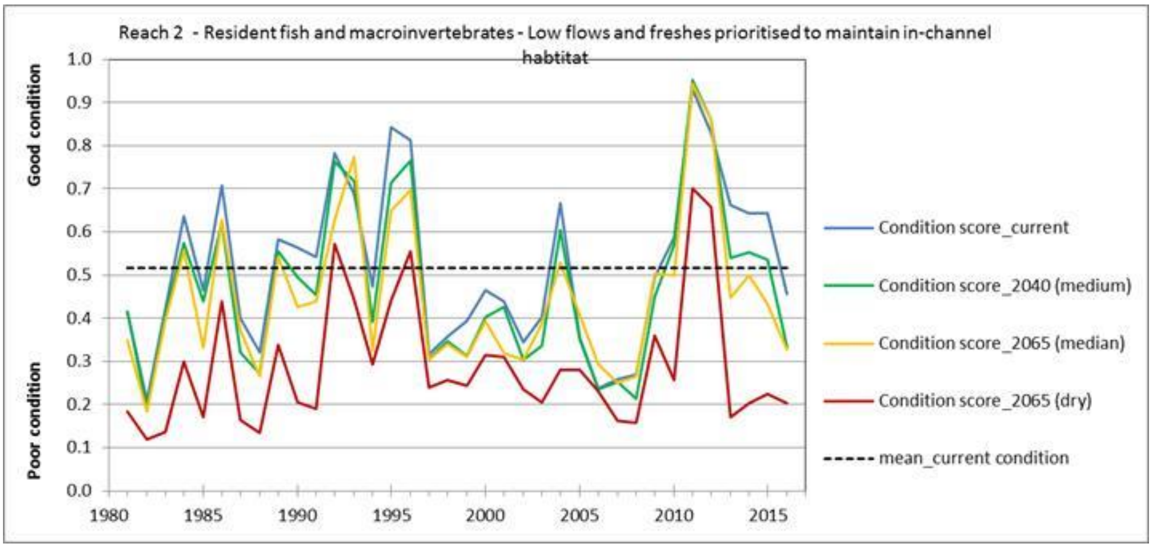
Figure 40 to Figure 45 show condition scores for all water dependent values. The results show that predictions for climate change indicate that in the short term (i.e. the next 15 to 20 years), the condition of values is likely to be similar to that under current conditions. However, in the long term, especially in dry climate years, condition is expected to deteriorate. Moreover, the results show that even under current conditions, conditions for most values in Reach 2 are lower poorer than conditions for similar values in Reach 6. As discussed earlier, this is because Reach 6 benefits from tributary inflows that help provide additional unregulated flow and results in a higher level of compliance with flow recommendations, including under climate change conditions.

With the current Environmental Water Reserve it will be difficult to maintain current ecological conditions, let alone improve them, as per the current Healthy Waterway Strategy objectives. In order to meet the current management and environmental flow objectives under a climate change outlook (i.e. maintain the current level of achievement with environmental flow recommendations) an increase in the volume of the Environmental Water Reserve will be required. This is especially the case for Reach 2 because of the lack of unregulated tributary inflows that would otherwise help to provide additional environmental flow.

13.4.1 Key summary points

Key points to note from the analysis and the graphs below are that:

- Reach 2 generally exhibits poorer flow conditions than Reach 6. This is because of the benefit unregulated tributary inflows make to the flow regime in Reach 6.
- Values at greatest risks are resident fish (e.g. River Blackfish), macroinvertebrates and platypus in Reach 2 because of the potential reductions in low flows and freshes which are important for maintaining access to habitat and for maintaining the quality of habitat.
- Migratory fish in Reach 2 may be less significantly affected due to the benefits of tributary inflows.
- Even under current climate conditions, extended drought possess a significant risk to values, as evidenced by very low condition scores for most values during the 2000s Millennium Drought.
- Conditions in the short term (next 15 to 20 years) are likely to be similar to current, even with climate change.
- Long term (>40 years) condition is predicted to significantly deteriorate, especially under the dry climate outlook scenario.
- In the long term the existing Environmental Water Reserve will be insufficient to maintain current condition, let alone aim to improve condition.



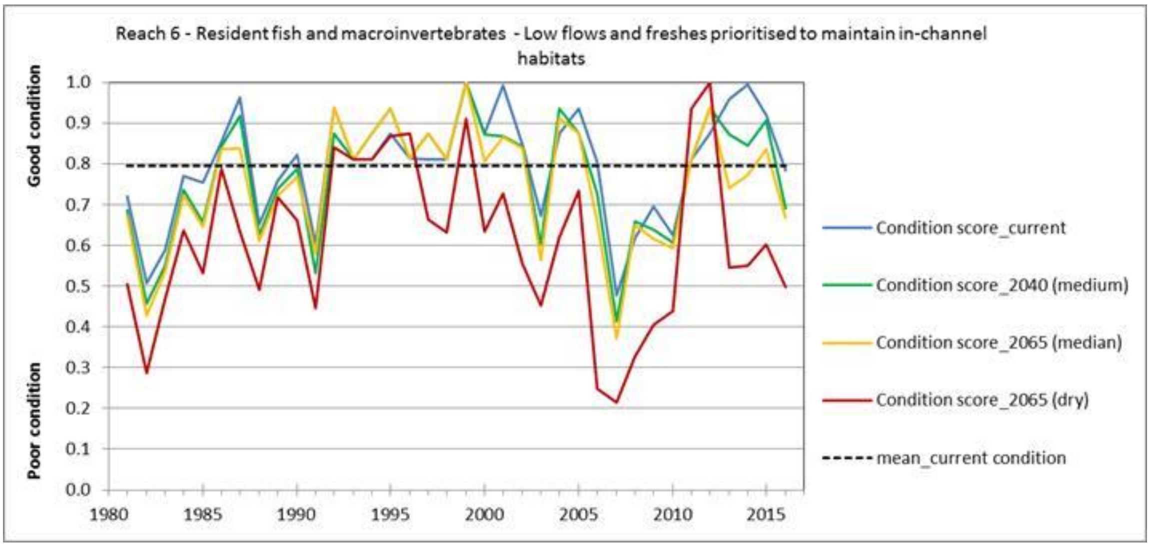
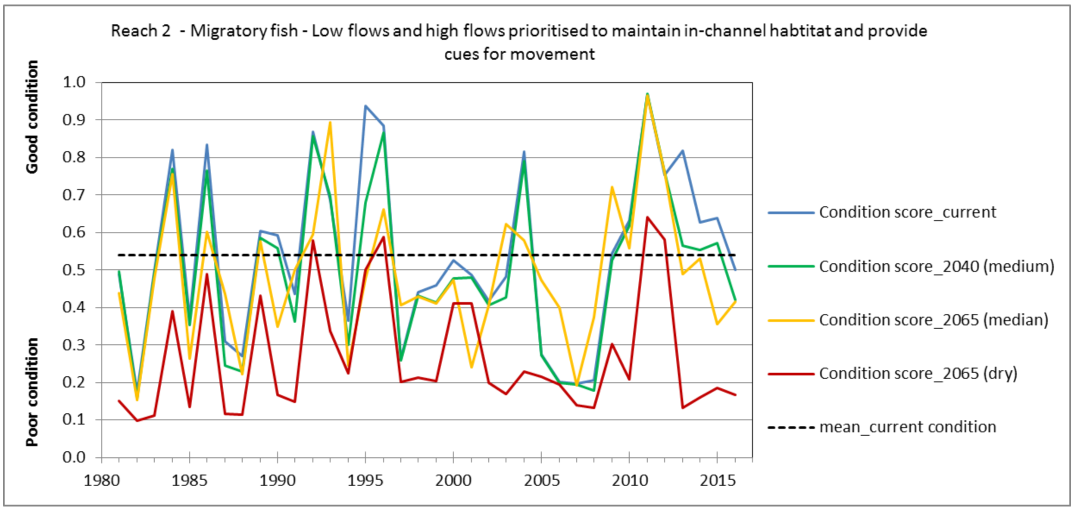


Figure 40 Time series condition scores for resident fish in Reaches 2 and 6 (prioritised for low flows and freshes

according to Table 21) under current and climate change scenarios.



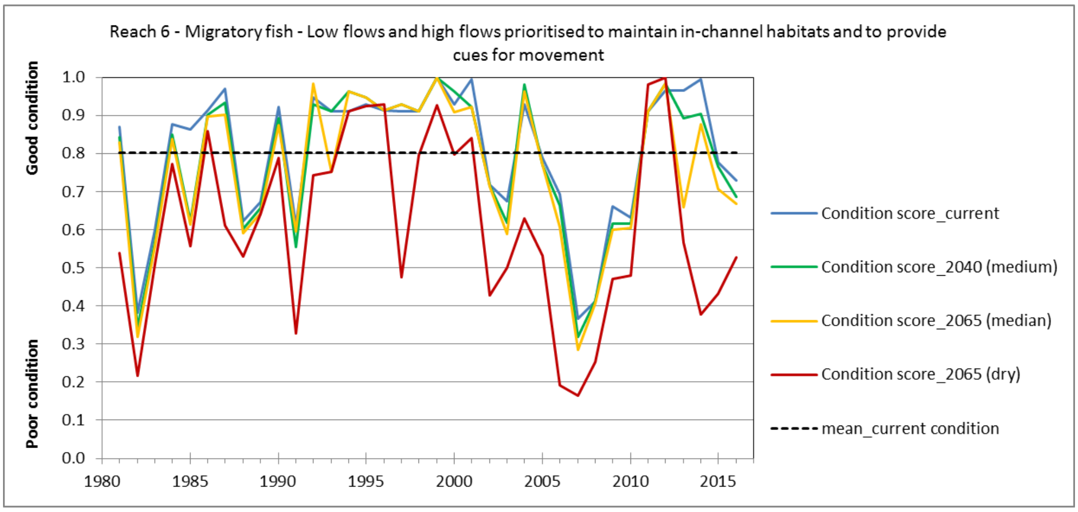
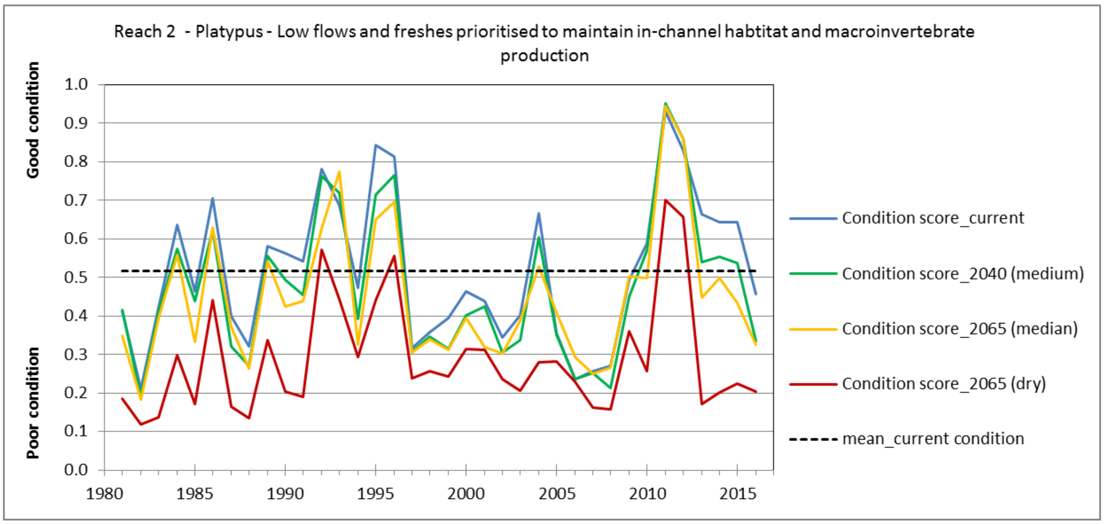


Figure 41 : Time series condition scores for migratory fish (prioritised for low flows and high flows according to Table 21) under current and climate change scenarios



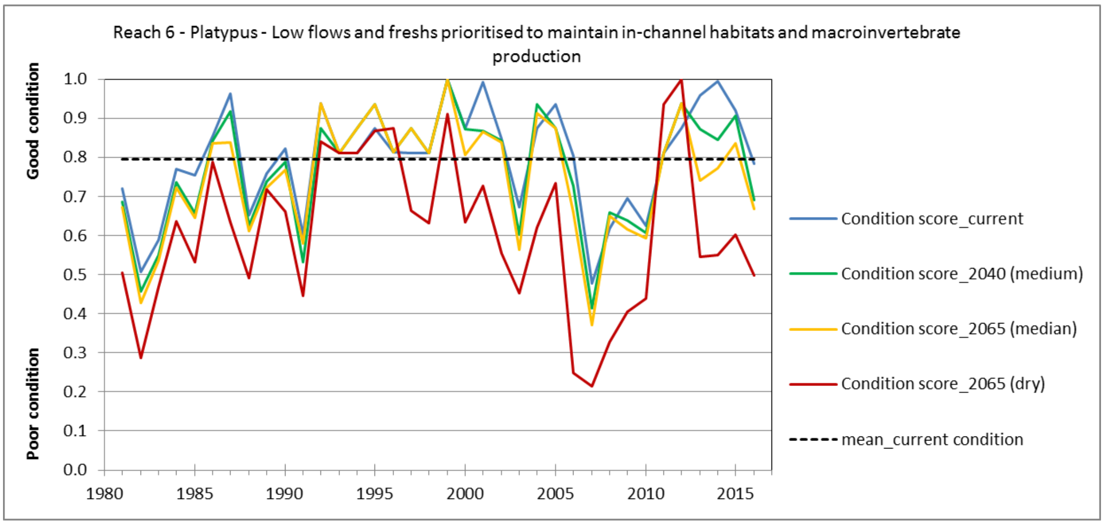


Figure 42 : Time series condition scores for platypus (prioritised for low flows and freshes to maintain access to habitat and promote food resources according to Table 21) under current and climate change scenarios.

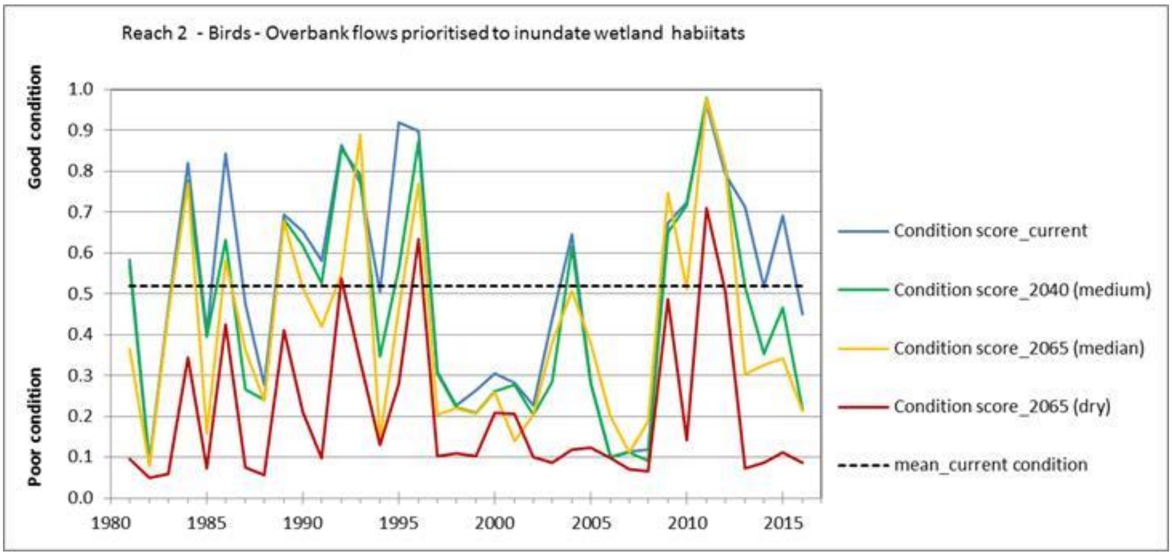


Figure 43 : Time series condition scores for Birds (prioritised for overbank flows to inundate wetland habitats according to Table 21) under current and climate change scenarios for Reach 2 (there are no overbank flow recommendations for Reach 6).

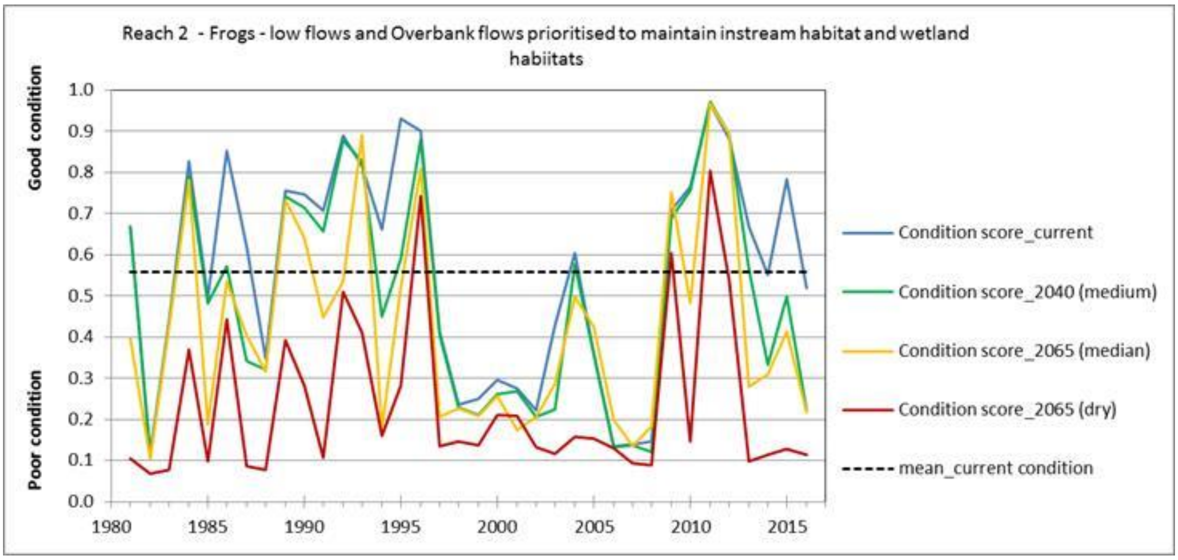
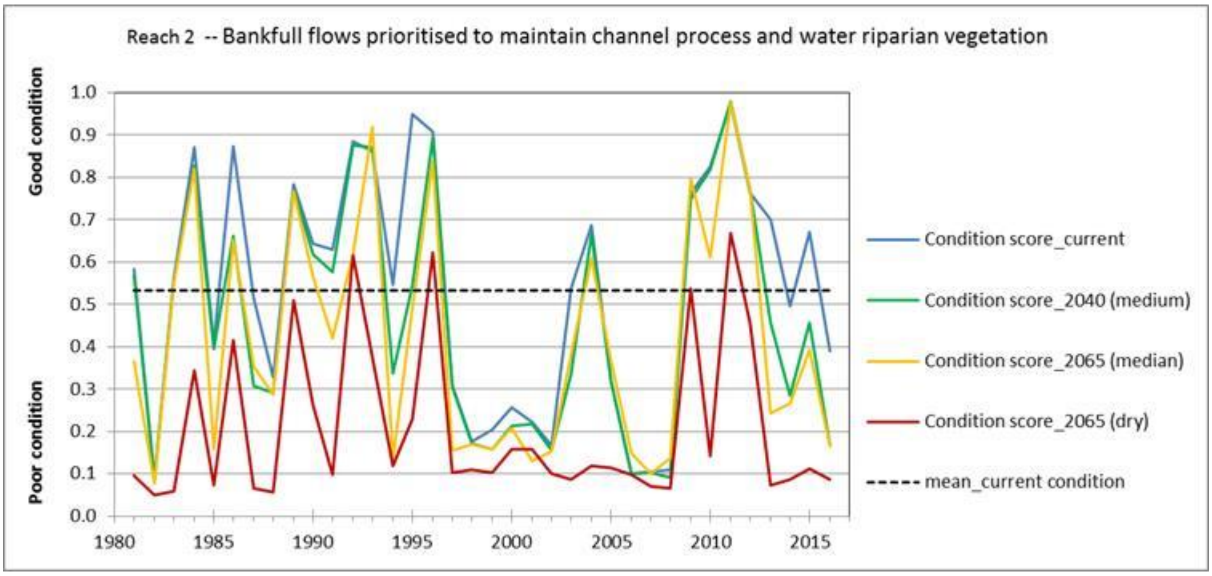


Figure 44 : Time series condition scores for Frogs (prioritised for low flows to maintain pool habitat and overbank flows to maintain wetland habitats according to Table 21) under current and climate change scenarios for Reach 2 (there are no overbank flow recommendations for Reach 6).



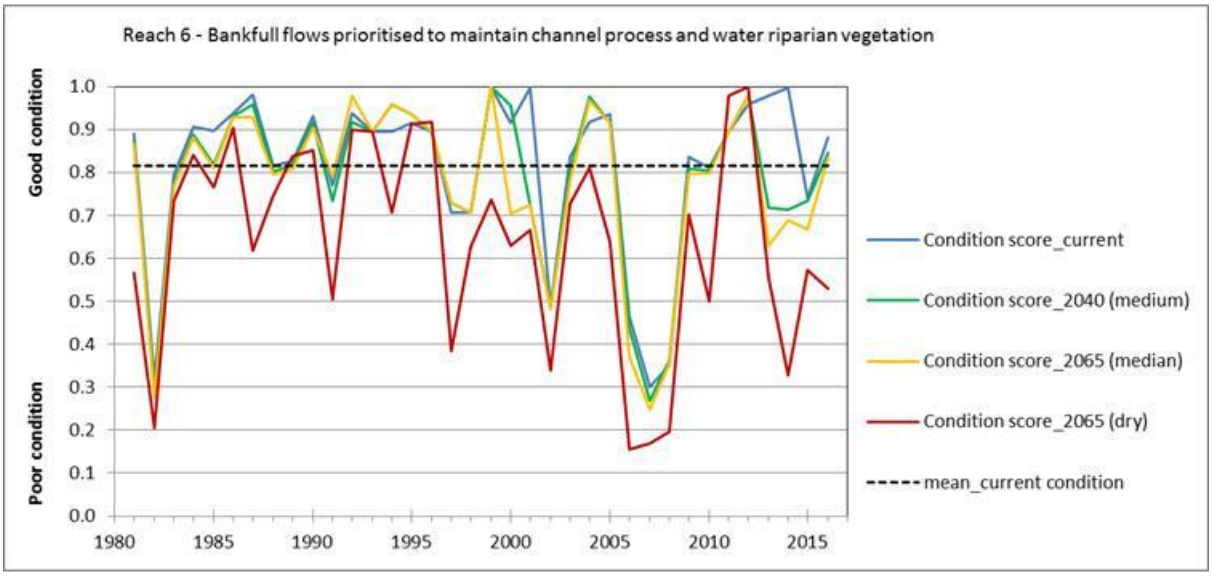


Figure 45 : Time series condition scores for Vegetation (prioritised for high flows and overbank flows to maintain soil moisture in banks and on the floodplain according to Table 21) under current and climate change scenarios.

13.5 Management actions

Climate change is a high priority for management actions by Melbourne Water and its delivery partners. While a significant risk, climate change provides a pathway for meaningful dialogue around what people value in the Tarago and Bunyip Rivers, and what is important to protect from a river health perspective as well as a community health and resilience perspective. There are good opportunities for Melbourne Water to build on its collaboration and engagement with delivery partners and the community, to achieve 'more and better' outcomes for the Tarago-Bunyip environmental watering program.

Value/issue	Threat	Implication	Actions
Climate change	Inadequate preparation for the impacts of climate change on streamflow and a compromised	Loss of condition for species and communities, local extinctions, decreases in abundance and	• Over the next 5 years, Melbourne Water will work towards improving understanding and planning for the impacts of climate

Value/issue	Threat	Implication	Actions
	ability to comply with environmental flow requirements	distribution, poor resilience of water-dependent communities.	change on streamflows in the catchment. • Melbourne Water will incorporate climate change knowledge into seasonal planning and projected demands, especially shortfalls. • Melbourne Water will also prepare a business case for improving on shortfalls, including exploring options to increase and/or augment the Environmental Entitlement.

Chapter 6 - Risk and Constraints

A range of risks and constraints can impact on the ability of environmental water releases to achieve the flow focused management objectives for the Tarago and Bunyip system.

14 Risks

When assessing risk to water-dependent ecological values in the Tarago and Bunyip system, Melbourne Water has sought to understand the following:

- The level of risk posed by threats to the water-dependent ecological values of the waterway, because this may impact on achieving the ecological objectives of the EWMP
- The potential negative risks associated with the broader waterway and catchment environment when watering targets (sometimes referred to as the 'third party components'), because these can reduce the gains achieved from more effectively managing environmental water.

In assessing the risks to water-dependent ecological values for the Tarago and Bunyip Rivers, the relationship between the likelihood (i.e. probability of occurrence) and the consequences of a risk occurring have provided the basis for evaluating the level of risk. Melbourne Water has undertaken a detailed risk assessment for all of its priority waterways receiving environmental water.

A summary of this risk assessment is shown in Table 22. It contains risk ratings and estimated residual risks following the implementation of successful management actions.

Management actions to address these risks are summarised in Appendix 9. Note that residual risk ratings are based on an assumption that these mitigation actions have been successful.

Key to risk table

	CONSEQUENCE				
LIKELIHOOD	**Negligible**	**Minor**	**Moderate**	**Major**	**Extreme**
Almost certain	Low	Medium	High	Extreme	Extreme
Likely	Low	Medium	High	Extreme	Extreme
Possible	Low	Medium	Medium	High	Extreme
Unlikely	Low	Low	Medium	High	Extreme
Rare	Low	Low	Low	Medium	High

RATING	DESCRIPTION
Almost certain	The event is expected to occur in most circumstances
Likely	The event will probably occur in most circumstances
Possible	The event might occur
Unlikely	The event could occur at some time
Rare	Event may occur only in exceptional circumstances

Table 22 : Risk assessment

Risk Category	Values Impacted	Likelihood (Almost certain / Likely / Possible / Unlikely / Rare)	Consequence (Negligible / Minor / Moderate / Major / Extreme)	Risk (Low / Medium / High / Extreme)	Residual Risk after Management Actions
RISKS TO ACHIEVING ECOLOGICAL OBJECTIVES					
Further consumptive extraction of surface water, causing an alteration of natural flow regimes	All	Possible	Major	High	Medium
Groundwater extractions causing shifts in the surface water/groundwater interface	All	Possible	Moderate	Medium	Low
Construction of additional artificial instream structures (e.g. dams, weirs, gauging stations)	All	Unlikely	Major	High	Medium
Recreational fishing	Fish Platypus	Almost Certain	Moderate	High	Medium
Land use change – Urban development and agricultural intensification and/or intensification	All	Likely	Moderate	High	Medium

Risk Category	Values Impacted	Likelihood (Almost certain / Likely / Possible / Unlikely / Rare)	Consequence (Negligible / Minor / Moderate / Major / Extreme)	Risk (Low / Medium / High / Extreme)	Residual Risk after Management Actions
Pest plants and animals: • Carp • Brown Trout • Gambusia • Redfin • Foxes, dogs and cats • Willows • Blackberries • Deer	All	Almost certain	Moderate	High	Medium
Illegal fishing nets (Opera nets)	Platypus Fish Birds	Almost certain	Major	High	Medium
Sediment inputs to the estuary	Fish Vegetation	Almost certain	Moderate	High	Medium
Stock access and grazing pressure	Vegetation Fish Platypus Amenity	Certain	Moderate	High	Medium
Climate Change	All	Almost certain	Extreme	Extreme	High

Risk Category	Values Impacted	Likelihood (Almost certain / Likely / Possible / Unlikely / Rare)	Consequence (Negligible / Minor / Moderate / Major / Extreme)	Risk (Low / Medium / High / Extreme)	Residual Risk after Management Actions
RISKS RELATED TO THE DELIVERY OF ENVIRONMENTAL WATER					
Winter high fresh drowns juvenile Platypus	Platypus	Possible	Major	High	Low
Environmental flow releases lead to safety risks to river users	N/A	Rare	Extreme	High	Low
Release volume is insufficient in meeting required flow at target point	All	Possible	Moderate	Medium	Low
Current recommendations on environmental flow are inaccurate	All	Possible	Moderate	Medium	Low
Storage Operator maintenance works affect ability to deliver water	All	Possible	Moderate	Medium	Low
Resource Manager cannot deliver required volume or flow rate (outlet/capacity constraints, insufficient storage volume) OR Competing storage operator priorities for flood and fire management do not allow delivery of some events	All	Possible	Moderate	Medium	Low
Releases cause water quality issues (e.g. blackwater, low DO, mobilisation of saline pools, acid-sulphate soils, etc)	All	Possible	Moderate	Medium	Low
Improved conditions for non-native species (e.g. carp)	Fish	Unlikely	Minor	Low	Low

Risk Category	Values Impacted	Likelihood (Almost certain / Likely / Possible / Unlikely / Rare)	Consequence (Negligible / Minor / Moderate / Major / Extreme)	Risk (Low / Medium / High / Extreme)	Residual Risk after Management Actions
Unable to provide evidence that hydrological target has been met	All	Possible	Minor	Low	Low
Environmental releases do not achieve planned/specified flow targets due to releases being diverted by other users before reaching delivery sites	All	Possible	Moderate	Medium	Low
Environmental releases cause unauthorised inundation of private land, resulting in impacts on landowner activities and assets	Amenity	Unlikely	Major	High	Low
Environmental release interferes with essential Melbourne Water services	N/A	Unlikely	Moderate	Low	Low
Inability to demonstrate outcomes achieved through environmental watering activities lead to a loss of public/political support	All	Likely	Moderate	High	Low
The environmental water account is overdrawn, leading to water not being available as per approved watering statement to complete planned actions	All	Rare	Minor	Low	Low
Community concern over environmental releases under dry seasonal conditions may lead to a loss of support for environmental watering activities	All	Possible	Minor	Low	Low
Public misperception of the purpose of releases	All	Possible	Moderate	Medium	Low

15 Constraints

Delivering environmental water to the Tarago/Bunyip system is subject to a number of constraints. These relate to limits on which reaches can be delivered to, the volume of water that is available in the Environmental Entitlement, and the security of the Environmental Water Reserve under low flow scenarios such as those created by drought and climate change. Constraints can also related to ecological requirements, such as ensuring some vulnerable species are not too disadvantaged by flow releases targeting management objectives for other species within the system.

15.1 Delivery constraints

15.1.1 Impacts from drought and climate change

The Environmental Water Reserve (EWR) is water protected from use for consumptive purposes under the *Victorian Water Act (1989).* The objective of the EWR is to assist in maintaining the environmental values and health of water ecosystems. The 3000 ML Environmental Entitlement is a small component of the EWR for the Tarago and Bunyip system, the remaining components being passing flows releases made under the Bulk Entitlements arrangements and any water that flows down the system (typically from tributary and groundwater contributions) which is not allocated for consumptive purposes (called above cap water). Figure 46 illustrates this concept.

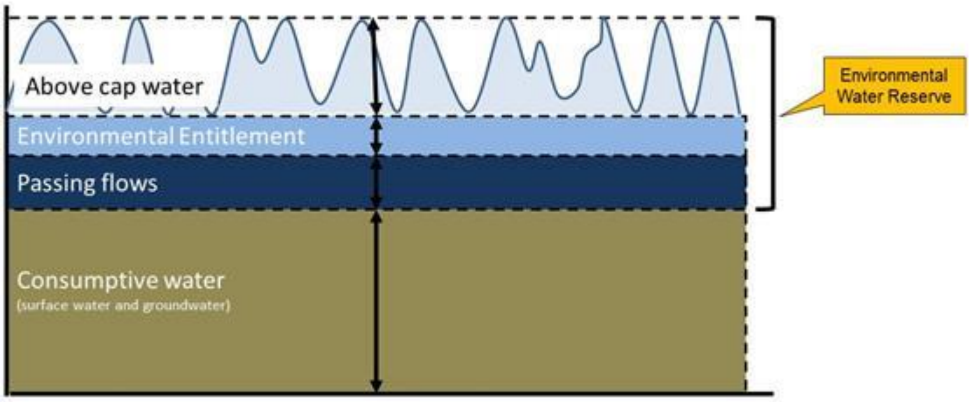


Figure 46 : Environmental Water Reserve components

Similar to other flow stressed waterways in Victoria, the Tarago-Bunyip Environmental Entitlement is of an inadequate volume to sustain the full suite of ecological objectives that have been determined through FLOWS studies, and this is likely to be exacerbated by any reduction of other water sources in the system. This is because Environmental Water Managers rely heavily on an assumption that other sources of water will still be available within a waterway, to further support the minimum flow releases they are able to provide from environmental entitlements and passing flows rules - the components of the EWR where they have most control over volumes and patterns of flow.

Furthermore, the flow recommendations provided through the FLOWS studies are the *minimum* requirements that scientists believe are necessary to assist in maintaining the ecological health and functioning of a small sub-set of the species and communities within the system. It is risky to assume that these flow recommendations will therefore maintain the full suite of ecosystem services and ecological functioning of the waterways if all other water is extracted from the system.

Constraints on annual accumulation of the Environmental Entitlement in storage

In a scenario where drought or climate change reduces streamflow in a system, the EWR is typically less secure than other types of water because its most significant component, above cap water, is vulnerable to variations in flows. The EWR is particularly vulnerable under long-term climate change because low streamflows can wipe out above cap environmental water completely. Although legally recognised as part of the EWR, above cap water is unregulated and uncertain. This is because it is entirely dependent on the level of inflows in each season and is only available when all other rights have been satisfied. Impacts to above cap water thus pose a threat and a significant constraint on the ability of Environmental Water Managers to comply with flow recommendations and achieve ecological objectives within a system.

In the upper Tarago River, Gippsland Water is entitled to divert water from Pederson Weir at an average amount of 4,070 ML per year[14], after allowing for passing flows below the weir. This water is piped via the Warragul Supply Main to Warragul Water Treatment Plant (WTP), where it is treated and used for supply to communities such as Warragul, Drouin, Buln Buln, Rokeby, Nilma and Darnum. Water is diverted from the Tarago River at Pederson Weir at a maximum rate of 12.6 ML/day after passing flows rules have been met[15].

The Warragul water supply system draws from the Tarago River upstream of the reservoir. For this reason, the system is more susceptible to drought impacts and, in the longer term, the increasing demands for water due to climate change and population growth in the region. As diversion demands increase, there is likely to be less above cap water available downstream of the weir to augment the passing flows. Inflows to Tarago Reservoir are impacted during times of low flow and/or increasing demand, and as a consequence, the accumulation of the Environmental Entitlement may also be vulnerable.

Alternative Sources of Water

In partnership with DELWP, Melbourne Water and VEWH may explore the feasibility of using alternative sources of water to increase or augment the Environmental Entitlement when streamflows are low in the Tarago/Bunyip system. There are a range of alternative water sources that may be available for the catchment e.g. recycled water, stormwater. There may also be opportunities to integrate these sources of water into an integrated water management strategy that includes consideration of Environmental Entitlement.

15.1.2 Management actions

Value/issue	Threat	Implication	Actions
Urban development	• Increasing water demands and extraction from Pederson Weir	Accumulation of the Environmental Entitlement volume is considerably slowed down, impeding the ability to provide appropriate flow volumes	• Melbourne Water will work with key delivery partners to understand the likelihood and consequences of increasing demands for extraction at Pederson weir. • Melbourne Water will work with key delivery partners to explore the feasibility and risks of using alternative water to augment the Environmental Entitlement.

15.1.3 Infrastructure constraint – Cannibal Creek

Releases from the 3000 ML Environmental Entitlement can currently only be made from Tarago Reservoir. This limits the reaches that can be targeted for environmental flows to

[14] This is a rolling average, calculated over five consecutive years.

[15] Passing flows rules at Pederson Weir are:

- 15 ML/d or the natural flows if inflow to Pederson Weir is greater than 700 ML over the previous 30 days; or
- 7 ML/d or natural, if inflow to Pederson Weir is less than or equal to 700 ML over the previous 30 days.

Reach 2, Reach 6 and Reach 7 respectively. Other reaches within the system must rely on natural catchment inflows and flows from other water supply infrastructure, such as the Bunyip Main Race and Tarago Main Race. Overcoming infrastructure constraints is an important issue for Melbourne Water to address over time to ensure the maximum benefit can be gained from the environmental entitlement.

For example, approximately 12 km upstream from the confluence of Cannibal Creek and Bunyip River, the Bunyip Main Race (BMR) crosses Cannibal Creek. For the past 15 years, water has been diverted from the Bunyip Weir, along the BMR and returned to the Bunyip River via Cannibal Creek. The magnitude of these flows is believed to be a maximum of 6-8 ML/d along the Cannibal Creek, comprising some 56% of the flow to the creek. In a system that would be expected to cease to flow during the summer season, this increase in flow is thought to be sustaining environmental values that may not otherwise be supported in this area, such as Dwarf Galaxias. Now that these values have become established in the area, they need to be managed.

Decommissioning is proposed for the BMR and the associated Tarago Main Race (TMR), which, without management, would see a decrease in the volume of water passing through Cannibal Creek. Without a good understanding of the current conditions of water dependant assets along Cannibal Creek (and also the BMR itself), and their environmental flows requirements, it is difficult to effectively manage the risks to these values from decommissioning the BMR. Melbourne Water has commissioned a project to confirm the environmental values present in the system, assess their environmental flow needs, and assess risks to the current flows if the BMR is decommissioned (Jacobs Draft in Prep 2017). This project will provide recommendations for a suitable compensatory flow regime to help protect important water dependent values in the Creek if required.

15.1.4 Management actions

Value/issue	Threat	Implication	Actions
Decommissioning of BMR and TMR	Possible loss of environmental water to Cannibal Creek	Loss of habitat and poorer habitat quality for key threatened species such as Dwarf Galaxias	• The findings and recommendations of a Cannibal Creek flows review will be incorporated by Melbourne Water into future FLOWS study reviews. • Melbourne Water will also use this knowledge to explore a range of options for maintaining flows to Cannibal Creek if required.

15.1.5 Protecting environmental flow releases

Delivery arrangements for environmental flow releases have been agreed upon with the storage operator and other key stakeholders, and over the past ten years, achievement of an environmental flow recommendation in Reach 2 has also resulted in the achievement of the recommended flow events in Reach 6. The only exceptions to this have been during periods when irrigation demands have been high (for example during the summer of 2006/07 in the final years of the Millennium Drought, prior to the Environmental Entitlement being established). Protecting environmental releases throughout the length of the system will be important in ensuring the maximum ecological benefit is achieved. Melbourne Water is managing this issue through non-watering actions such as working with Southern Rural Water (SRW) to manage local diverters during releases.

The 2013 review of the environmental flow recommendations (SKM, 2013) amended the recommended duration of the Spring (migration) and Autumn (spawning) High Flow events in Reach 2 for migratory fish, particularly for Australian Grayling. The new recommendations have provided significant challenges for managing the entitlement as they extend the duration of the release by a number of days and increase the volume of water required.

Under dry condition scenarios only partial achievement of the current flow recommendations is possible because there is insufficient water available. Under these scenarios, Melbourne Water aims to provide the previous flow recommendations as listed in Table 23 for these events. These flows are considered a partial achievement because some aspects of the ecological objectives may still be achieved. Monitoring will be undertaken over the next few years to determine the effectiveness of the amended recommendations, particularly for Australian Grayling. Melbourne Water will also review the outcomes of delivering smaller events, to compare the effectiveness of each delivery strategy for Australian Grayling.

Table 23 : Updated environmental flow recommendation (SKM, 2013) – Delivery Constraints

Flows	Previous Recommendation (Earth Tech, 2007)	Current Recommendation (SKM, 2013)
Autumn High Flow	200 ML/d for 1 day (or natural) April - May	One event greater than seven days (or natural) duration which peaks at 100 ML per day for longer than 2 days delivered in April or May
Spring High Flow	280 ML/d for 1 day (or natural) Late October - November	280 ML/d for 4 days (or natural) Late October - December

15.1.6 Ecological constraints

Connecting the floodplain

Bankfull and overbank flows are also important in the Tarago/Bunyip system. These flow components generate and maintain scour holes to create habitat and are important in establishing riparian vegetation. However, due to potential flooding risks on private land, infrastructure constraints and the volume of water required to deliver these flow components they are currently not actively managed, but they may occur naturally.

In Victoria there is increasing recognition of the importance of reconnecting rivers to their floodplains, and over the next 5 to 10 years, Melbourne Water will explore the feasibility of working with landowners to deliver targeted and strategic overbank flows to areas of the system where flood risks and/or impacts can be mitigated and minimised.

Reducing risks to platypus

With improved knowledge of the flow requirements of platypus, it will be important to assess the possible ecological constraints of providing flows to known communities downstream of Tarago Reservoir and in Reach 6. A key requirement is making sure that high flows do not drown platypus babies while they are still in the burrow, and Melbourne Water will incorporate this and other platypus flow requirements in to future FLOWS study review and the environmental watering program for the Tarago/Bunyip system.

River Blackfish

Recent monitoring has shown decreasing numbers of River Blackfish in the system. Prioritisation for flows that benefit Australian Grayling may be disadvantaging Blackfish numbers in the waterways, particularly large flow pulses (e.g. 'summer fresh' and 'summer high') over their spawning and recruitment/post recruitment period (November to around March/April).

The environmental flow requirements of River Blackfish will be thoroughly reviewed and compared against the existing flow recommendations to determine if a different set of flow requirements are needed to be established specifically for the species. This approach will be complimentary to other existing intervention programs such as willow removal and woody debris reintroduction, which cumulatively may be critical to ensure the long term viability of River Blackfish populations. Ongoing monitoring will also assist in further understanding this concern.

15.1.7 Management actions

Value/issue	Threat	Implication	Actions
Australian Grayling	Gaps in knowledge still exist regarding Australian Grayling ecology and links with flow	• Inadequate flow regime to maintain resilience of the species • Consequent reduction in abundance and distribution or possible local extinctions	• Melbourne Water will conduct further research to better understand the influence of flow regime on immigration and upstream dispersal. • Melbourne Water will implement the Australian Grayling recommendations from ARI (2017).
River Blackfish	River Blackfish numbers are declining, with evidence of poor recruitment. Climate change could exacerbate threats.	Loss/extinction of the species from the catchment	• Melbourne Water will review environmental flow requirements for River Blackfish and update seasonal planning as necessary. • Complementary actions to protect and improve habitat availability and quality.
Floodplain connectivity	Bankfull and overbank flows are not provided	• Loss of habitat and poor habitat for species/communities dependent on floodplain areas. • Consequent reduction in their abundance and distribution. • Possible local extinctions	• Over the next 5 to 10 years, Melbourne Water will explore the feasibility of delivering targeted and strategic overbank flows to areas of the system where flood risks and/or impacts can be mitigated and minimised.
Platypus	New knowledge not incorporated into platypus management strategy	• Drowning of platypus babies • Poorer habitat quality and availability • Reductions in population abundance and possible local extinctions	• Melbourne Water will incorporate new platypus knowledge in to the environmental watering program for the Tarago/Bunyip system and adjust flow provisions where identified. • Platypus knowledge will be further reviewed and incorporated into the next review of the environmental FLOWS study.

To maximise the benefits of the Tarago-Bunyip Environmental Entitlement it will be necessary to find ways to overcome the current delivery constraints. Options that could be considered include:

- Investing in new environmental entitlement delivery infrastructure
- Utilising existing infrastructure owned by other organisations

- Improving the ability to time environmental releases with rainfall events
- Investigating opportunities to access alternative water supplies to provide environmental flows events
- Optimising the consumptive water supply system to derive additional environmental benefits from this water.

Melbourne Water will continue to explore the feasibility of each of these options with key delivery partners.

Chapter 7 - Demonstrating Outcomes

Carefully designed monitoring and research programs help Melbourne Water to judge the robustness of the Tarago/Bunyip environmental watering program in terms of its ability to meet both management objectives and desired outcomes for key values. These programs also help to improve work planning and generate new knowledge.

16 Monitoring and research programs

To improve the understanding the Tarago/Bunyip system more broadly, Melbourne Water is undertaking the following:

- Using a streamflow gauge installed in 2011, continuing to undertake streamflow monitoring on Labertouche Creek to improve understanding of streamflows in the system
- Using a rainfall/runoff model to optimise the releases from the reservoir in relation to catchment contribution
- Analysing travel times in the system through the release and monitoring of environmental watering events
- Managing planned releases to maximise the benefits to the environment of spill rules
- Reviewing River Blackfish locations to better understand their environmental water requirements
- Incorporating the research of Australian Grayling and River Blackfish monitoring into the watering program
- Incorporate findings from platypus environmental water requirements research into a review of the environmental FLOWS study when appropriate
- Monitoring and further investigating the benefit of access to airspace in the system.

16.1 Monitoring

The Tarago/Bunyip monitoring programs cover a range of activities, including:

- Compliance monitoring (such as hydrological monitoring) – To determine if environmental flow release targets have been met
- Short-term event monitoring – To determine if environmental values are responding in the short-term to watering events
- Long-term ecological response monitoring and research – To determine if short-term environmental responses are leading to long-term changes
- Long-term condition/health monitoring – To track trends in the condition of values over time.

Melbourne Water's Knowledge, Innovation and Research Program outlines a number of monitoring and research projects that contribute knowledge about the flow needs of the Tarago/Bunyip system. These are briefly described in Table 24.

Table 24 : Monitoring, research and investigations programs

Monitoring/Research activity	Description
Australian Grayling migration and spawning	In recent years Melbourne Water has been investigating the spawning habits of Australian Grayling in the Tarago River. The research is aimed at improving understanding of the conditions required for a spawning event to occur, and to determine if an environmental release can successfully bring about a spawning response. There is currently a limited understanding of what triggers juvenile Australian Grayling to move from the estuary to upstream reaches. Melbourne Water in conjunction with ARI has successfully trialled an otolith[16] analysis technique that may assist in determining the timing of fish moving from estuarine to freshwater conditions. Research using this technique is ongoing. Melbourne Water is also currently investigating combining research and knowledge with catchment management authorities to further its understanding of Australian Grayling from a regional perspective.
Melbourne Water Urban Platypus Program	Melbourne Water funds the Urban Platypus Program, a yearly monitoring event that surveys platypus populations every spring and autumn within the Greater Melbourne Area. Population abundance, recruitment success and individual animal condition are among a range of factors that are assessed. The program has been running for the past 20 years.
Fish surveys	Fish surveys are undertaken in the Tarago and Bunyip on a regular basis to help monitor the health of the fish populations. The first sampling was undertaken in December 2016 with a follow up in March 2017. Outcomes of the surveys feed into flow release planning.

16.2 Compliance

Compliance with environmental flow provisions is monitored by Melbourne Water using a series of flow gauges throughout the Tarago/Bunyip catchments (Table 25).

Table 25 : Reaches and their streamflow gauges for monitoring purposes

Reach	Extent	Gauge
Reach 1	Upper Tarago – Pederson Weir to Tarago Reservoir	Tarago River at Neerim (228206)
Reach 2	Lower Tarago - Tarago Reservoir to Bunyip River confluence	Tarago River at Drouin West (228201)
Reach 3	Labertouche Creek	Labertouche Creek at Longwarry North (228290) (installed July 2011)
Reach 4	Upper Bunyip - Bunyip State Forest to Tarago River confluence	Bunyip River at Tonimbuk (228212)
Reach 5	Cannibal Creek	No gauge
Reach 6	Bunyip Main Drain	Bunyip River at Iona (228213)
Reach 7	Bunyip Estuary	Bunyip River at Koo Wee Rup (228395)

[16] A fish otolith is a calcium carbonate structure of the inner ear, made up of layers of inert tissue. Each year, additional layers are laid down, storing the isotopic signature of the water occupied by the fish. Otoliths can provide a persistent record of movement between rivers and estuaries over the life of diadromous fish.

These gauges along the river allow monitoring and reporting on the achievement of flow components through releases. As the resource manager, Melbourne Water is required to keep account of the volume of water released from the Environmental Entitlement, which is in accordance with accounting principles that are outlined in the Operating Arrangements for the management of the Environmental Entitlement.

For releases from the Environmental Entitlement (i.e. released from the VEWH's account), accountability for the volume ordered to be released lies with the Melbourne Water Waterway Manager, while accountability for the actual volume released lies with the Melbourne Water Storage Manager. The Storage Manager meters and maintains records of the VEWH's share of system inflows, releases, and changes in storage. This information is provided to the Resource Manager to account for the VEWH's and other entitlement holders shares of water in storage. During environmental water deliveries, the Waterway Manager provides the VEWH with a weekly report, and on the completion of priority watering actions, provides an event summary.

During the development of each year's Seasonal Watering Proposal, Melbourne Water undertakes a review of the previous 12 months to consider:

- How long term flow regimes compare to the recommendations of the flows study
- The degree to which releases from the Environmental Entitlement have met priority watering actions
- Any key issues relating to the management of the Environmental Entitlement from the most recent season.

Melbourne Water has developed a targeted monitoring program to assess the impact of particular flow events in achieving the ecological objectives, and has also developed a Knowledge, Innovation and Research Program to guide its broader monitoring and research requirements in the area of environmental flow delivery.

16.3 Evaluating and reviewing the environmental watering program

It is important to interpret and evaluate the monitoring, investigation and research data at regular intervals and translate these into useful actions and improvements for the environmental water management program. Melbourne Water undertakes its evaluation and review processes according to a framework called the MERI framework, where MERI stands for 'Monitoring', 'Evaluating', 'Reviewing' and 'Improvement'. The MERI framework is used for Melbourne Water's environmental watering program, and establishes the program logic for the environmental watering evaluation and review process. The Seasonal Watering Proposal planning process also assists Melbourne Water in tracking the positive and negative impacts and outcomes of environmental flow releases for the Tarago and Bunyip Rivers.

16.4 Complementary actions

Flow-related actions are most effective when they form part of an integrated management approach that also aims to improve habitat quality, address connectivity issues, and reduce direct threats from human activities and pest plants and animals. A range of complementary actions are undertaken by Melbourne Water:

- Protecting and/or restoring native riparian vegetation corridors along stream and river banks and within wetland systems
- Removing willows and other invasive woody weeds from the waterway (while preventing bank erosion and maintaining adequate protective cover for platypus and waterbirds from predators)
- Reducing the adverse impacts of stock access along water courses by working with landowners to fence off waterways and creating off-stream watering points.

- Retaining and augmenting the amount of instream woody habitat (logs and large branches) present in stream and river channels and wetlands
- Undertaking community education programs to address illegal fishing nets use, and implement an education and involvement program with recreational fishing groups to ensure native fish are released but introduced fish are not released back in to the river
- Through strategies such as Water Sensitive Urban Design (WSUD), controlling and treating urban stormwater and agricultural runoff as needed before it enters natural water courses to reduce litter and concentrations of sediment and chemical pollutants
- Reducing the impact of introduced predators by implementing control programs for foxes/feral cats and by restoring/maintaining a dense band of plant cover along the edges of waterways to discourage easy access by foxes, dogs and cats, especially in places where water is shallow (seasonally or throughout the year). Undertaking community awareness programs to raise dog and cat owners' understanding of the risks these pets can pose to platypus and waterbirds.

Chapter 8 - Engagement, Knowledge and Next Steps

Melbourne Water has built on the already strong community networks within the region and with delivery partners to develop the EWMP. These networks will remain important to engage with for collaborative actions under the EWMP, for increasing understanding of the system, and for addressing knowledge gaps regarding environmental water management.

17 Consultation

Consultation and engagement undertaken by Melbourne Water during the development of the Healthy Waterways Strategy has significantly informed this EWMP, particularly in the choice of ecological objectives and key values. As a consequence, the consultation undertaken for the development of the EWMP was able to focus on:

- Ensuring key stakeholders were aware of the EWMP and that they understood its management objectives and priorities,
- Discussions and feedback regarding emerging issues such as climate change, urbanisation and water-dependent cultural values.

In order to develop the EWMP, the following consultation activities were undertaken:

- Identification and documentation of water-dependent values already assessed through consultation with community and key stakeholders for the Melbourne Water Healthy Waterways Strategy. This drove the engagement process that was needed for the development of the EWMP.
- Identification and documentation of the key stakeholders relevant to the EWMP, via a Stakeholder Engagement Strategy. The strategy was developed in consultation with Melbourne Water Project Manager, and consultation/engagement was undertaken only after the key stakeholders and objectives for engagement were identified, prioritised and endorsed.
- Developing an interactive Engagement Tool, which was updated throughout the project, and summarised the information currently known about the key values, their general flow requirements, and their management objectives. The Engagement Tool was distributed to participants in the project at the completion of the EWMP.
- Undertaking consultation with the Tarago and Bunyip Rivers Stakeholder Reference Group, consisting of:
  - Western Port Catchment Landcare Network
  - Bunyip Landcare
  - Drouin Landcare
  - Neerim and District Landcare
  - Jindivick Landcare
  - Irrigators and diverters
  - Glen Cromie Caravan Park
  - Southern Rural Water

- Gippsland Water
- Port Phillip and Western Port CMA
- WaterWatch (Melbourne Water)
- Environment Protection Authority (EPA)
- Parks Victoria
- Baw Baw Shire Council
- Cardinia Shire Council
- Friends of Robin Hood Reserve
- Native Fish Australia and VRFish
- Department of Environment, Land, Water and Planning
- Melbourne Water
- Victorian Environmental Water Holder

- Conducting a one day site visit, with attendance by members of the Stakeholder Reference Group, Local Government and Melbourne Water Waterways and Land Officers, to visit key sites along the waterways and discuss the key values and issues that should be included for discussion in the EWMP.
- Consulting with Melbourne Water staff responsible for the operational management of the Melbourne Headworks system, to understand system operations and constraints.
- Consulting with the Victorian Environmental Water Holder regarding emerging issues affecting the Tarago/Bunyip, particularly regarding cultural values management.

A range of the stakeholder feedback and responses regarding the development of the draft EWMP are included in Appendix 4.

17.1 Opportunities for communications and engagement

Melbourne Water recognises the importance of providing ongoing support for community groups and networks, and for programs which educate and engage the community about the values of the Tarago and Bunyip Rivers and encourage their protection. In developing the EWMP, the Stakeholder Reference Group's 20-year vision for the Tarago and Bunyip Rivers was to see greater community engagement and awareness of their values increase over time, and more opportunities for people to get involved in the broader river health program for the region (see Appendix 4). People also strongly noted that healthy rivers make for healthy communities, and suggested that there would be a wide variety of opportunities where Melbourne Water could help to facilitate a greater understanding of this connection within the community.

Using a variety of communications and engagement activities, Melbourne Water will continue to work with local communities and key delivery partners to:

- Empower and encourage more people to act in ways that benefit the waterways
- Better understand the barriers that prevent action, and then taking action to help overcome these barriers where possible
- Increase knowledge about when, what, where, how and why communities value the diverse range of values associated with the Tarago-Bunyip system.

In the lower reaches of the catchment, there are strong opportunities to engage and communicate about the impacts of land use change and the values and benefits of the habitat corridor and connectivity that the Bunyip Main Drain provides for fish, bandicoots and platypus. There are also opportunities to engage with communities about the importance of maintaining connectivity between the freshwater reaches, the estuary, and the receiving waters of Western Port. Facilitating a ‘mountains to sea’ perspective of the system will be important for protecting the freshwater reaches, the estuary and the internationally recognised Ramsar values within Western Port.

In the upper catchment, it will be important to continue engaging with communities regarding its high biodiversity and amenity values, particularly with respect to important habitat these reaches provide for threatened species, recreation opportunities, and connectivity to downstream flow regimes. With relatively unregulated waterways and less developed land in this part of the catchment, engagement and communications actions will focus on encouraging communities and key delivery partners to help protect and maintain these values.

Many Victorians contribute to biodiversity protection through citizen science projects such as Waterwatch, which collects important baseline information about waterways by assisting with biodiversity monitoring. The ever-growing use of technology such as smartphone apps also facilitates the collection of environmental observations by individuals, and over the next 5 to 10 years Melbourne Water will explore innovative ways to use these emerging strategies to assist in river health and environmental water management in the Tarago and Bunyip catchment. For example, an interactive engagement tool was developed by Jacobs to assist in the consultation and development processes for the EWMP, and Melbourne Water will explore the possibility of turning this prototype into an App.

A high level internal Communications and Engagement Strategy has been developed to support the implementation of the EWMP and the ongoing management of the Tarago-Bunyip environmental watering program by Melbourne Water. The two main objectives of this Strategy are:

- To assist Melbourne Water (and the VEWH) in maintaining and improving the effectiveness of the environmental watering delivery program for the Tarago-Bunyip system
- To strengthen processes that support inclusiveness and integration of community and key delivery partner perspectives, to support ‘more and better’ outcomes for the environmental watering program.

In light of these objectives, a broad range of actions are included in the internal Strategy which will wholistically function to:

- Maintain and improve the two-way information flow between stakeholders and Melbourne Water - through meetings, presentations and site visits for example
- Provide clarity and transparency about how stakeholder input influences decisions, helping to maintain trust - through inclusive and two-way interactive consultation processes
- Integrate stakeholders’ knowledge and experience into decision making and solution building processes - including engagement with Traditional Owners, a key opportunity for Melbourne Water over the next 5 to 10 years
- Evaluate, monitor and collect feedback regarding the strengths and weaknesses of the environmental watering program - through ongoing engagement with researchers, experts and the community
- Ensure that Melbourne Water provides a ‘public face’ for the Tarago-Bunyip Rivers environmental watering program across the community and actively engages with communities regarding this topic, through social media strategies.

This Strategy will be treated as a ‘living’ document by Melbourne Water, updated when and as needed to ensure that two-way communications and engagement remains appropriate, tailored and effective. As emerging issues become known, the Strategy will also be reviewed to ensure that key stakeholders with influence on and/or interest in these issues continue to be included.

18 Priority knowledge gaps and actions to address

A considerable amount of knowledge has assisted in the determination of the environmental flow regime for the Tarago and Bunyip Rivers. However, because the science of environmental flows is relatively new, this knowledge base is incomplete. The 2006 and 2013 environmental flows studies recommended minimum flow requirements for the waterways and while these studies have advanced our scientific knowledge of the system, there remain large gaps in our understanding of key species and their flow requirements, as well as the associated ecological processes. The environmental objectives developed for the studies were necessarily limited by this knowledge gap.

It is important that future advances in knowledge or methodology are incorporated into the data and evidence base used to manage environmental flows for the system. A range of knowledge gaps are discussed briefly below.

18.1.1 Estuary

A preliminary review of flow requirements for the estuary was undertaken by EarthTech for the 2006 flows study, but no full flows study has been conducted. There is little information available on the consequences of flow regulation in headwater areas for coastal ecosystems, but there are suggestions that it could be significant. Strong positive correlations have been observed between seagrass distribution and sediment inputs from the Bunyip River for example, and further research is required to investigate these causal mechanisms and to develop predictive models using ecological responses and flow data.

A dedicated study to assess environmental flow requirements for the Bunyip estuary using the Estuary Environmental Flows Assessment Method for Victoria (EEFAM) would help improve the understanding of the flow requirements in the estuary and more generally in Western Port.

An important flow-related objective will be managing the hydraulic thresholds that control erosion and sediment movement in the Bunyip Main Drain, and the hydraulic thresholds that determine if sediment will be deposited or eroded from benches that can be colonised by instream plants under suitable conditions. The hydrology of the estuary is highly modified from natural, and all flow components (high, medium and low flows) will potentially have important roles in maintaining estuary health, and will thus require further investigation.

18.1.2 Platypus

The current understanding of the flow requirements of platypus in the Tarago and Bunyip River system needs improvement. It will be particularly important to improve understanding of the existing platypus population, including its resilience and appropriate condition/response assumptions for different water availability scenarios under climate change. Surveys of platypus abundance and distribution through Melbourne Water's annual Urban Platypus Program (MWUPP) will also assist in improving this knowledge. The surveys, held every spring and autumn, identify threats to the species, insights into the steps to mitigate these threats and monitor the response of platypus to river health works. An innovative new application being trialled by Melbourne University, cesar and Melbourne Water for the MWUPP is the analysis of environmental DNA samples (eDNA) to detect the presence and relative abundance of platypus throughout the Melbourne area (Jacobs *et al.* 2016). This technique analyses genetic material collected not through targeted methods such as trapping, but extractions from bulk environmental samples such as water (Barnes and Turner 2016).

18.1.3 Waterbirds and frogs

Very little is known of the environmental flow requirements of waterbirds and frogs in the Tarago and Bunyip catchments. For example, flow requirements for frog species such as Growling Grass Frog are not well known, particularly regarding the extent of dependence this species may, or may not have, on flows from the main stem of the rivers or their connected floodplains. The dependence of waterbirds on the freshwater reaches is also poorly understood. This work will necessarily be a long term strategy for Melbourne Water given the current paucity of data on species and community abundance and distribution over time. Understanding the impacts of climate change on migratory bird species within the catchment will be particularly important given a number of these species are protected under international covenants and are endangered on a global basis. Conducting surveys and habitat profiling will assist Melbourne Water to understand the relationship between inundation events and use of the waterways, including the antecedent conditions that are favourable for breeding.

18.1.4 Amenity and recreation

Given the priority that people place on waterway amenity values, it will be important to be able to link these values with flow requirements where they are known. Melbourne Water is undertaking significant work to determine what aspects of amenity can be managed by the provision of flows and how outcomes for amenity objectives can best be monitored and measured. Melbourne Water's Strategic Asset Management Plans, as well as the next revision of the Healthy Waterways Strategy, will be further developing this knowledge, and as new methodologies are developed through these strategies this information will also inform future revisions of the EWMP. The revision of the Healthy Waterways Strategy will be completed in 2017-18.

18.1.5 Water-dependent cultural values

Currently there is very little knowledge available for waterway managers to help ensure that water-dependent cultural values are protected and managed appropriately and sensitively in Australia. Melbourne Water and VEWH are exploring the feasibility of conducting a collaborative project with the Wurundjeri, Bunurong and Gunai Kurnai people to determine the water-dependent cultural values of the Tarago and Bunyip Rivers and the likely flow requirements of these values, with a view to being able to provide co-beneficial watering of these values.

The findings of such a project would inform Melbourne Water's annual environmental flow planning processes, as well as VEWH's seasonal watering strategies. Collaborative management of the waterways between Aboriginal and non-Aboriginal people will likely highlight a wide range of knowledge gaps and weaknesses. Future versions of the EWMP, as well as other strategic management documents, will be regularly updated to reflect this increasing knowledge base.

18.1.6 Groundwater

Targeted hydrogeological assessments, particularly if coordinated with hydrological and ecological survey and monitoring, will improve the understanding of the role of groundwater in the Tarago and Bunyip catchments. In this way, dramatic changes in contributions from (and to) groundwater can be better accounted for in the environmental flow recommendations.

19 Next steps

This EWMP provides the overarching strategy for the management of environmental water and protection of water-dependent values in the Tarago/Bunyip system for the next ten years. It will provide the basis of annual planning for the management of the entitlement, most notably providing the direction for future Seasonal Watering Proposals and the development of Melbourne Water's environmental water annual work program.

Figure 47 shows the contribution of EWMP information towards the annual seasonal planning processes for both Melbourne Water and VEWH. The numbers in brackets in the Tarago/Bunyip EWMP box correspond to the numbered topics in the Seasonal Watering Proposal box.

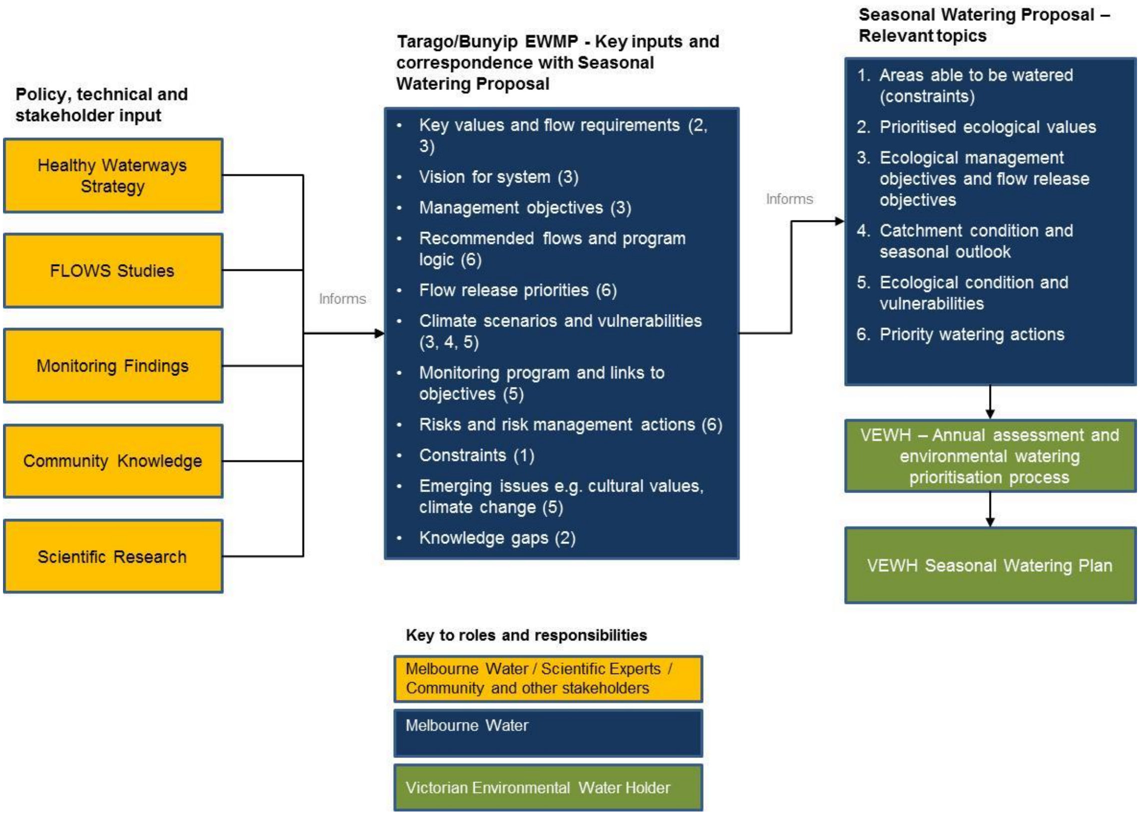


Figure 47 : The contribution of EWMP information to Seasonal Watering Proposal content

This EWMP will also be used to inform the review of technical information underpinning the Environmental Entitlement, including for the upcoming review of the environmental flows study in 2018/19.

The EWMP will also provide the basis of future inputs to Melbourne Water strategic documents, including the review of the current Healthy Waterways Strategy, which is due for completion in 2017/18. In addition to internal strategies, the EWMP will allow Melbourne Water to advocate for improved outcomes for water dependent values in the Tarago and Bunyip Rivers through State Government policy reviews and strategies, such as the review of the Central Region Sustainable Water Strategy.

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Tarago and Bunyip Rivers Environmental Water Management Plan

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Appendix 1. Rights to water

Holder	Bulk Entitlement	Annual Entitlement Volume (ML)
Primary Entitlements with carryover		
City West Water Corporation	Bulk Entitlement (Greater Yarra System – Thomson River Pool – South East Water) Order 2014	An average annual amount of: • 24,950 ML at Tarago Reservoir • 5,560 ML at the Bunyip Weir • Over any consecutive 5 year period
South East Water Corporation	Bulk Entitlement (Greater Yarra System – Thomson River Pool – South East Water) Order 2014	
Yarra Valley Water Corporation	Bulk Entitlement (Greater Yarra System – Thomson River Pool – South East Water) Order 2014	
Barwon Water Corporation	Bulk Entitlement (Greater Yarra System – Thomson River Pool – South East Water) Order 2014	
South Gippsland Water Corporation	Bulk Entitlement (Greater Yarra System – Thomson River Pool – South East Water) Order 2014	
Westernport Water Corporation	Bulk Entitlement (Greater Yarra System – Thomson River Pool – South East Water) Order 2014	
Western Water Corporation	Bulk Entitlement (Greater Yarra System – Thomson River Pool – South East Water) Order 2014	
Primary Entitlements without carryover		
Central Gippsland Regional Water Corporation	Towns supplied by Gippsland Water from Tarago Reservoir under the **Bulk Entitlement (Tarago – Gippsland Water) Conversion Order 2009**	
Gippsland and Southern Rural Water Corporation	Releases from Tarago Reservoir for Southern Rural Water's private diverters under the **Bulk Entitlement (Tarago River – Southern Rural Water) Order 2009**	
Environmental Entitlement		
Victorian Environmental Water Holder	Tarago and Bunyip Rivers Environmental Entitlement 2009	The environmental entitlement in consists of 10.3% of net reservoir inflows and a passing flow requirement of 12 ML/d at Drouin West. On average the environmental entitlement should receive 2,000 ML per year in inflows (Melbourne Water 2015).

19.1 Water harvesting and storage

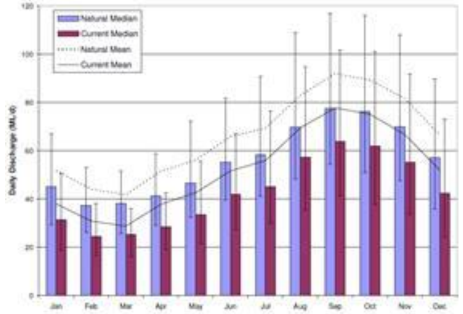
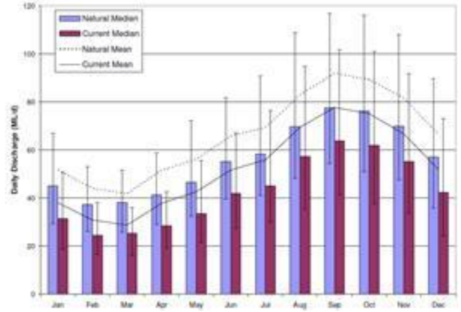
The largest water storage in the system, with a capacity of 37,580 ML is the Tarago Reservoir, which was completed in 1968 (Melbourne Water undated). Originally, untreated water was transferred from the reservoir to supply local townships and the Mornington Peninsula and Westernport via the Tarago-Westernport Pipeline (Melbourne Water undated). The reservoir had a history of water quality issues, however, including blue-green algal blooms, and was removed from the supply system in 1994.

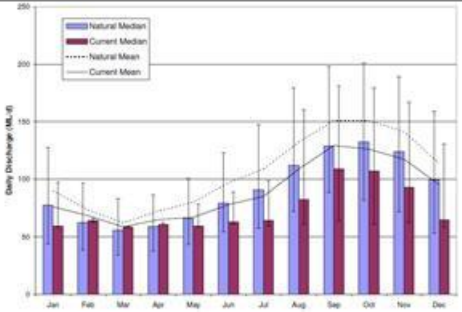
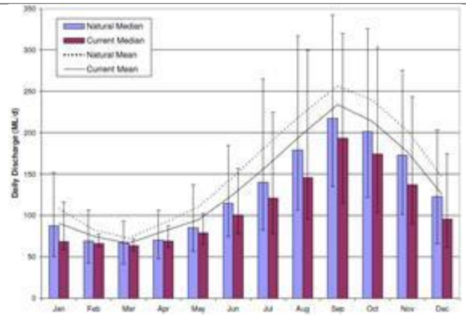
The reservoir was reconnected to the system in 2009, with the completion of the Tarago Water Treatment Plant (WTP). The WTP can treat 70 ML a day (Melbourne 2016) which is used to supply potable water to the Mornington Peninsula, Gippsland, Westernport and can be transferred into the Melbourne system.

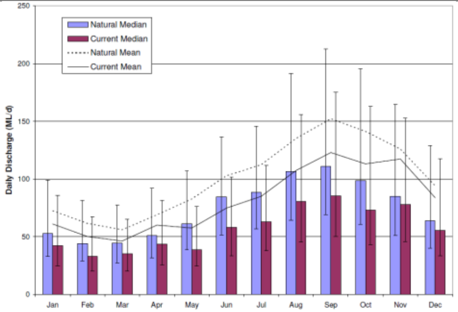
Appendix 2. Summary of hydrology for each reach

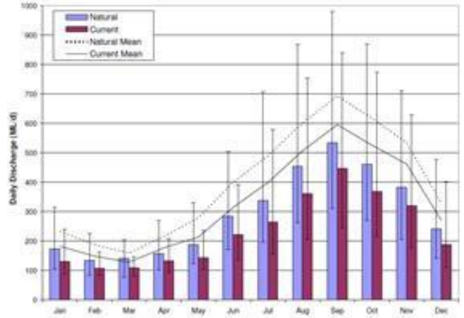
Table 26 provides a summary of changes in each reach of the Tarago and Bunyip system as a result of regulation.

Table 26 : Hydrological changes by reach (Source: Adapted from EarthTech (2006)

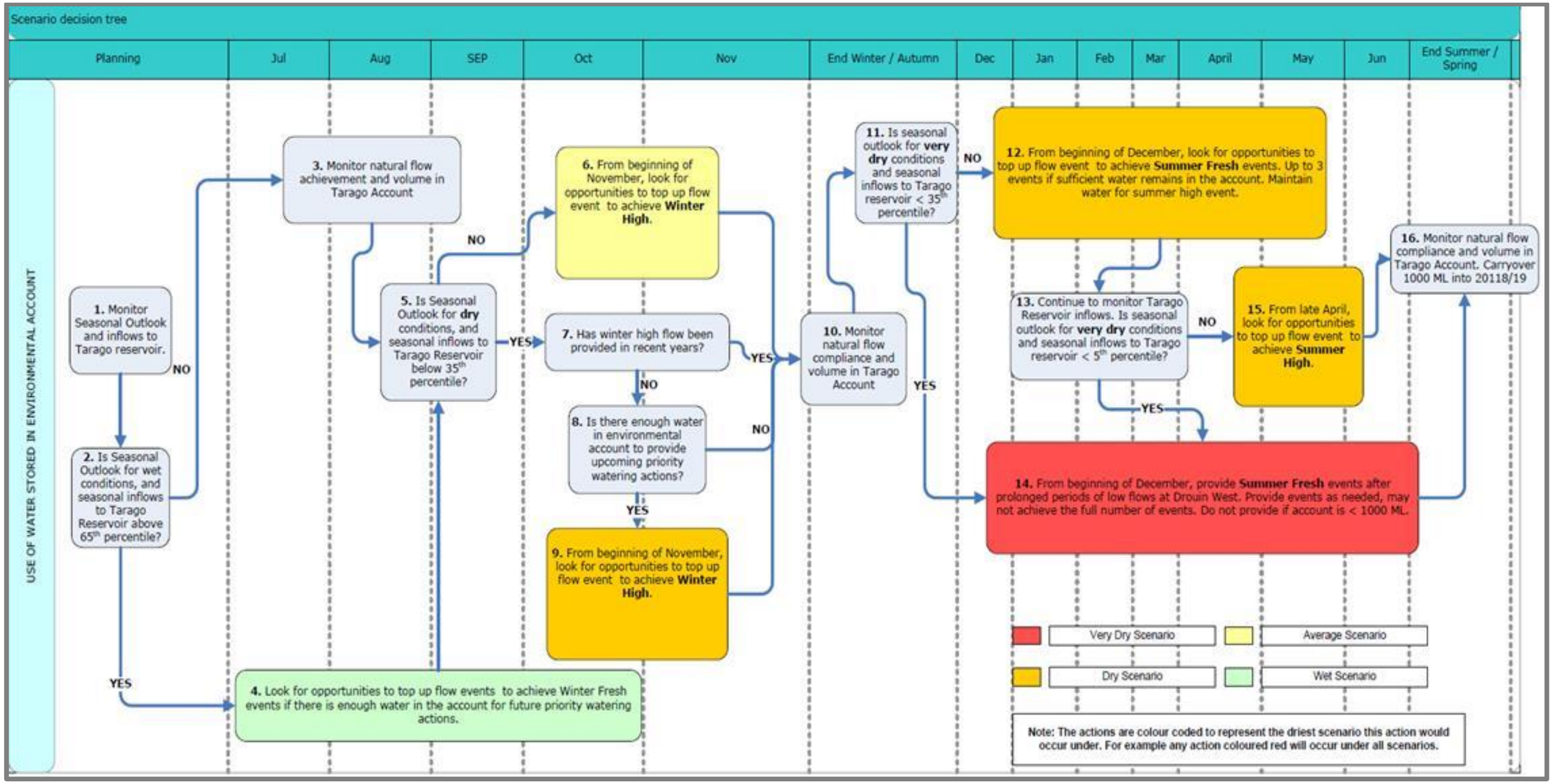
Reach	Current Flow Regime	Natural (i.e. pre regulation) Flow Regime	Changes to Seasonality	Changes to Flooding	Hydrograph
1 - Tarago River East Branch: Upper Tarago River	Mean annual flow of 3,590 ML/year	The natural flow regime would have been similar to what is it today as very little modification has occurred.	Periods of no flow would not have occurred under natural conditions and do not occur now.	N/A	
1 - Tarago River at Neerim: Upper Tarago River	The mean annual flow of 19,120 ML/year which is a decrease of 21% on natural conditions. There has been a 35% reduction in median monthly flows No zero flows occurred naturally or under	Under natural conditions, mean annual flow would have been 24,173 ML/day.	Seasonality has been well preserved but there is generally a reduction in flow, particularly in the low flows.	N/A	

Reach	Current Flow Regime	Natural (i.e. pre regulation) Flow Regime	Changes to Seasonality	Changes to Flooding	Hydrograph
	current conditions.				
2 - Tarago River at Neerim South: Lower Tarago River	The mean annual flow of 32,476 ML/year which is a decrease of 16% on natural conditions. Low flow months (Feb-April) flow variability has been significantly reduced. In high flow season there has been a considerable decrease in mid-range flows, exceeded 30 to 80% of the time.	Under natural conditions, mean annual flow would have been 38,790 ML/day.	Seasonality has been well preserved but significantly impacted by Tarago Reservoir releases.	The flood flows occurring at a 2 year recurrence interval have been reduced from 700 to 450 ML/d.	
2 - Tarago River at Drouin west: Lower Tarago River	The mean annual flow of 50,101 ML/year which is a decrease of 12% on natural conditions . Significant variability in the variation of the flow regime during the low	Under natural conditions, mean annual flow would have been 56,871 ML/day.	Seasonality in this section of the reach has been mostly restored.	The magnitude of floods has not been significantly impacted	

Reach	Current Flow Regime	Natural (i.e. pre regulation) Flow Regime	Changes to Seasonality	Changes to Flooding	Hydrograph
	flow months (Feb-April). Smaller flows are more common and larger flows are less common. High flow months, there has been a reduction of the mid-range flows, around the 50% exceedance				
3 - Labertouche Creek	Labertouche Creek is not gauged and therefore there is no information about the changes since regulation. It is expected that the flows would be reduced compared to natural due to irrigation demands and flow stress in winter due to filling of the minor storage on the creek.				
4 - Bunyip River at **Tonimbuk: Upper Bunyip River**	The mean annual flow of 29,844 ML/year which is a decrease of 19% on natural conditions. There is a general reduction throughout the range of flows for all seasons. The variability in the flow regime has generally been retained through the low flow	Under natural conditions, mean annual flow would have been 36,738 ML/day.	There is some preservation of seasonality but also some considerable impacts of regulation.	Flood flows have not been significantly impacted by current conditions.	

Reach	Current Flow Regime	Natural (i.e. pre regulation) Flow Regime	Changes to Seasonality	Changes to Flooding	Hydrograph
	months.				
5 - Cannibal Creek	Cannibal Creek is not gauged and therefore there is no information about the changes since regulation. It is expected that the flows would be reduced compared to natural due to irrigation demands. There is no storages on Cannibal Creek and therefore there is not expected to be flow stress in winter due to filling of storages.				
6 - Bunyip River at Iona: Bunyip main drain	The mean annual flow of 119,751 ML/year which is a decrease of 17% on natural conditions. A general reduction in monthly discharges, some minor impact on the variability in low flow season.	Under natural conditions, mean annual flow would have been 144,605 ML/day.	There is a general seasonality retained.	There has been a general reduction in flood magnitudes.	

Appendix 3. Climate scenario decision tree



Appendix 4. EWMP development stakeholder feedback

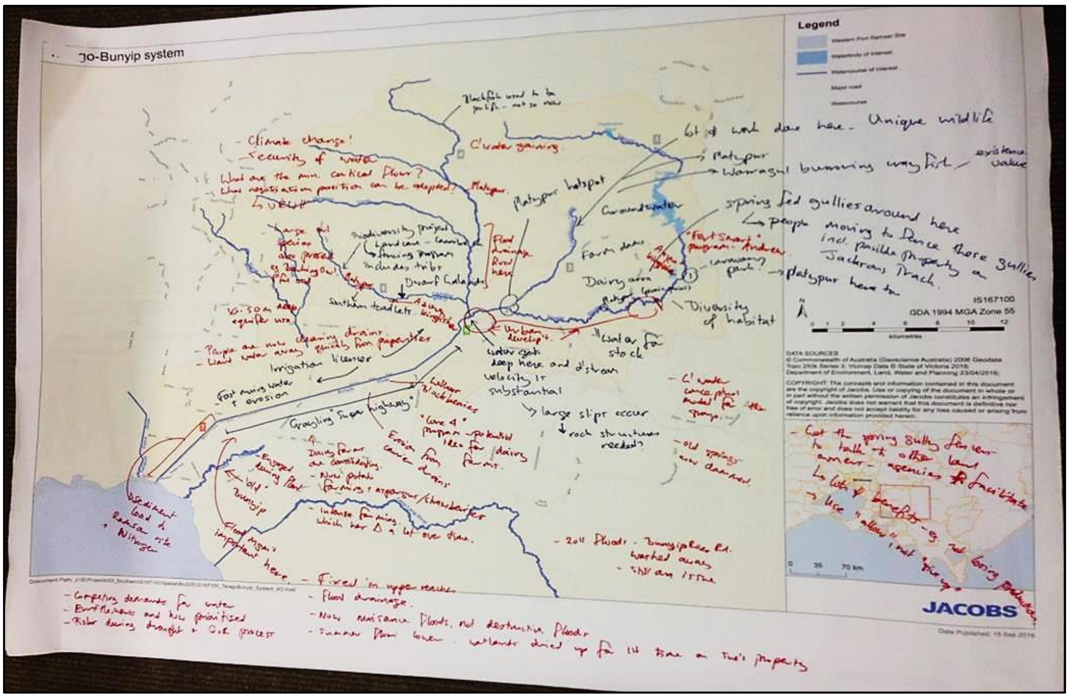


Figure 48 : Stakeholder Reference Group feedback provided during the development of the EWMP regarding key values, threats and land uses in the Tarago and Bunyip catchments.

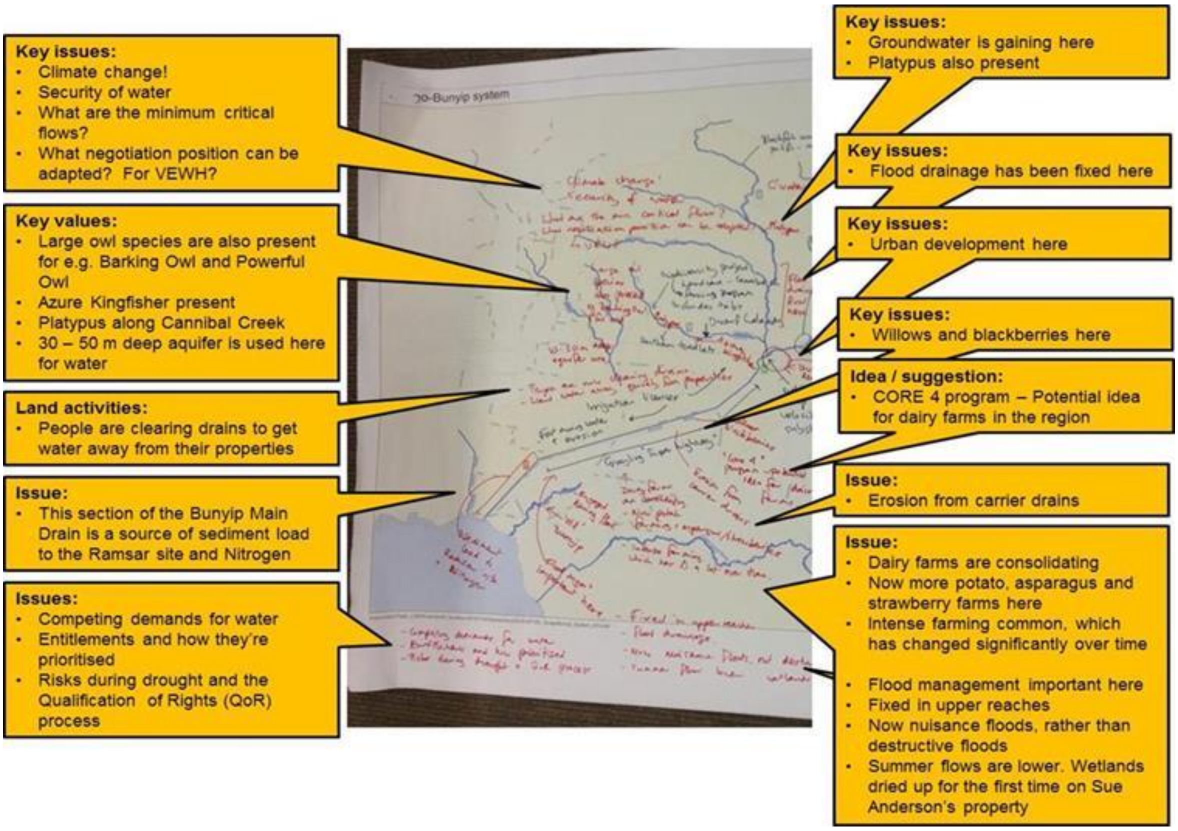


Figure 49 : Transcribed notes from left side of Figure 48 map

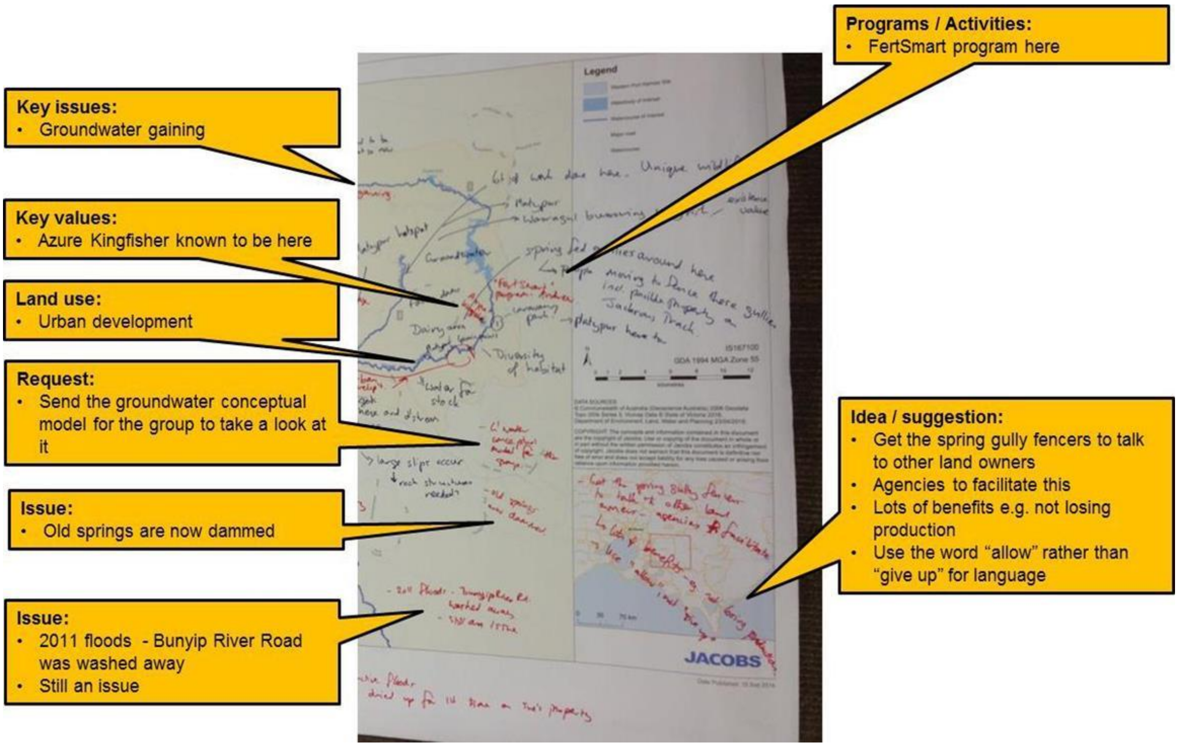


Figure 50 : Transcribed notes from right side of Figure 48 map

Figure 51 : Stakeholder Reference Group vision statements and management objectives, from stakeholder consultation during the development of the EWMP

Appendix 5. Threats

Threat	Description	Key Values Impacted
Altered hydrology	With extensive modifications to the timing, duration and volume of the natural flow regime, regulation has significantly altered the hydrological character and functioning of the Tarago and Bunyip Rivers. This has implications for their values in terms of: • Changes to, or even the loss of, important flow pattern cues for migration, mating and spawning behaviours for aquatic fauna • Habitat availability, for example the maintenance of connectivity to floodplains and billabongs, which may function as nursery areas for juvenile fish; and the loss of pools, riffles and other river physical qualities which will reduce the amount of available habitat for shelter and feeding opportunities for platypus and birds • Habitat quality, where reduced flows may increase the temperature of pools, decrease dissolved oxygen levels and increase salinity to beyond the tolerance thresholds of aquatic flora and fauna • Loss of connectivity, with a reduction in opportunities for dispersal and recolonisation, reducing the diversity and abundance of aquatic biota • Lack of food resources reducing overall floodplain and billabong productivity For fauna species, this can result in • A reduction in the diversity and abundance of food sources • Stable water levels and open water habitat favouring introduced fish such as Redfin Perch, which prey on small native fish. • A consequent reduction in species diversity and abundance.	All
Climate Change	This threat is discussed in Section 13.	All
Barriers to fish movement, including reduced connectivity to the floodplain and wetlands	The capacity to move is crucial to fish recolonisation after disturbance and to allow fish to move within and between habitats when seeking food and shelter, for mating and spawning, and for migration. Fish movement along the River channels and laterally across the floodplain and/or into wetlands can be obstructed by barriers to their passage. Large dams, weirs, regulators, levees and road crossings can also act as barriers, and can apply upstream and downstream, as well as laterally onto the floodplain. Tarago Reservoir is the only major potential instream fish barrier that exists on the Tarago River.	Fish Macroinvertebrates Platypus
Urbanisation and increased Directly Connected	Increased DCI can increase the inputs of polluted water into waterways and reduce water quality, and can significantly change the flow regime of the system. This alters the availability and quality of habitat for biota. For example, high velocity stormwater inputs can damage and uproot instream vegetation, cause bed and bank erosion issues, and	All

Threat	Description	Key Values Impacted
Imperviousness (DCI)	increase the amount of sedimentation within the waterway. This threat is discussed in greater detail in Section 4.1.	
Water Quality	Poor water quality was the reason for withdrawing the Tarago Reservoir from service. Concerns about the catchment include high levels of colour, turbidity, nutrients, faecal coliforms, iron in manganese in both the water of the reservoir and in the surrounding catchment (EarthTech 2006c). Agricultural practices are considered to be a major contributor to poor water quality. These practices include: • Use of high nutrient fertilisers – increasing the risk of algal blooms; • Animal wastes – contributing to the presence of coliforms; and • The presence of cattle and other livestock on agricultural land with reduced vegetation cover – contributing to soil erosion and resulting in surface transport of sediment and pollutants into the reservoir. The main nutrients in the waterways come in the form of inorganic N and P. Only small amounts of each are required in a natural ecosystem and any additional increase can quickly become a nuisance by causing excessive algae and plant growth. An increase in the available nutrients in waterways is called eutrophication, which can have severe environmental effects. An increase in algae growth, sometimes called an algal bloom, reduces DO in the water when the algae die and decompose and it also reduces water clarity, reducing the ability of some animals to see prey or predators. If the cycle happens repeatedly, species may be lost from the waterway. Increased nutrient inputs from the freshwater reaches of the Tarago and Bunyip River may also cause severe eutrophication of Western Port, reducing habitat availability and quality, and reducing the recruitment and survival of migratory, estuary and marine derived animal species. Rivers are also natural depositories for pollutants that have come from higher in the catchment or from use of their floodplains for agriculture, industry or urban populations. The Tarago and Bunyip Rivers have received atmospheric and water-borne industrial and urban toxicants for well over 100 years. The broad pathways and sources for toxicant include surface water inflows; groundwater discharges and atmospheric deposition. Toxicants that pose a threat include heavy metals, pesticides, herbicides and aromatic hydrocarbons. Other toxicants that pose a threat, particularly in urban landscapes, are polychlorinated biphenyls (PCB's). All of these toxicants can have significant effects on plants and animals, including death, impaired health, and loss of condition.	All
Bushfires	Biota in bushfires experience increased water temperatures and ash and debris deposits into the waterways as the flame front passes. This can reduce dissolved oxygen and increase pH, nutrient loads and temperatures, which can cause fish kills (SKM 2009). Ash and sediment from the surrounding catchment also washes into the stream where it can smother fish gills, eggs, pools and food sources. The ash also reduces dissolved oxygen. The heavier silt and gravel will settle in the vicinity of the fire, but fine ash and silt can travel a long distance, affecting biota lower in a catchment.	All
Introduced fish	Introduced fish species, such as Carp, Goldfish, Roach, Tench, Redfin and Mosquito Fish, compete with native fish for food and habitat, can negatively impact on habitat availability and quality, can introduce disease to native fish populations, and can also prey on smaller fish and frog species. Competitive behaviour that excludes native fish from food resources and habitat, as well as aggressive interactions in confined environments have also resulted in reduced condition of native fish and reduced population sizes and distribution.	All

Threat	Description	Key Values Impacted
	These fish compete with native fish for food and habitat, and also prey on smaller fish species (MDBC 2003). For example, Carp now make up an estimated 60 to 90 per cent of the total fish biomass at many sites, with densities as high as one carp per square metre of river surface area (MDBC 2003). When carp are present in high densities, the resultant suspended sediment can result in a number of problems, including the direct deterioration of water quality due to sediment and increased nutrient levels, reduced plant growth, the clogging of gills of other fish species, and fewer plant species because they have either been eaten or uprooted (Rowe *et al.* 2008).	
Sediment	Although sediment and its associated effects on water clarity and turbidity is an inherent component of aquatic systems, there is an increased risk to the survival and well-being of fish when levels exceed background values for a particular period of time. Sedimentation can be harmful by acting directly on aquatic fauna in the water, either killing them or reducing their growth rate, resistance to disease etc. It can also: prevent the successful development of eggs and larvae; modify natural movements and migrations; reduce the abundance of food available; and affect the efficiency by which animals can catch or harvest their foods.	All
Disease – Chytridiomycosis (Chytrid fungus)	Chytridiomycosis is a water-borne and often fatal fungal disease that mostly affects amphibian species associated with permanent water, such as streams and wetlands. Since its first recorded appearance in Australia, the fungus has been directly implicated in the extinction of at least four species and the dramatic decline of at least 10 others, including the Growling Grass Frog.	Frogs
Foxes, dogs and cats	Predation by foxes, dogs and cats when platypus travel overland or in shallow water to find suitable foraging habitats and burrows, is major threat to the species. Foxes and cats have been classified as keystone species in Australia because by preying on native animals, they have reduced biodiversity and impacted on the survival of native animals over large areas of entire ecosystems. For example feral cats have been implicated as a threat to 142 species and sub-species, comprising 40 mammal species and sub-species (Woinarski *et al.* 2014), 40 birds, 21 reptiles and four amphibians (Department of the Environment 2015). Predation by foxes, dogs and cats can also cause the loss of eggs, chicks and adult birds, and the presence of these predators in an area may deter breeding.	Platypus Birds Frogs
Introduced/pest plants	Invasive plants outcompete native plants for habitat, and in some cases are harmful to native animals that eat them. Aquatic weeds can reduce light penetration, reducing photosynthesis by submerged aquatic plants and reducing the oxygen levels in the water. Reduced light can inhibit visual feeding by fish and movement by platypus, and reduced oxygen levels may be fatal to fish. Aquatic weeds can also smother waterways, and they can greatly alter flow rates. This reduces native species diversity and abundance. Willows are particularly problematic for waterways because they clog up the channel with their large matted roots, consume large amounts of water via transpiration, and out-compete native plants. Willow infestations on the riparian zones of rivers are known to impact on the ability of platypus to build burrows, and also reduce the availability of food sources for them (Serena and Williams, 2008 in SKM 2012b).	All
Desnagging	Snag or timber removal was once a very common management practice along the Yarra River and its floodplain waterways, with de-snagging practices aimed to improve stream flow, reduce severity of flooding, and improve the passage for boat navigation. Aquatic and terrestrial floodplain flora and fauna require woody habitat for: • In-stream habitat • A food source	Fish Macroinvertebrates Platypus Birds

Threat	Description	Key Values Impacted
	• Sites to spawn and rear juveniles • Protection from strong currents and sunlight • Orientation points to identify habitat and territory • Shelter from predators • Vantage points to help capture prey (Treadwell *et al.* 1999). Removing these timber structures has a huge impact on entire food chains (Treadwell *et al.* 1999) and efforts are now made to restore snags to riverine environments.	
Degradation or loss of riparian vegetation	Riparian vegetation clearance reduces stream shading. Research in Victoria during the Millennium Drought showed that streams with intact catchment and riparian vegetation started in better condition prior to drought conditions and remained in better condition throughout the drought (Thomson *et al.* 2012). Evaporation of water from pools is exacerbated with the loss of riparian shade, and can lead to a decline in water quality as levels of dissolved oxygen decrease and salinity increases.	All
Recreational and commercial fishing	Recreational and commercial fishing directly remove fish species from the river, estuary and Bay, reducing overall population abundance and injuring individuals that survive. Recreational fishing can negatively impact the abundance of native fish species. This is particularly a problem during periods of drought when the habitat availability for fish can already be considerably reduced. Illegal fishing nets are known to trap and kill platypus. The behaviours of some fish species, such as Macquarie Perch, place them at higher risk of population depletion from fishing because they gather together in larger groups in preparation for movements upstream over the spawning season. Opera House nets used to catch yabbies have trapped and drowned Platypus in Labertouche Creek.	Fish Platypus Birds Macroinvertebrates
Domestic stock access and grazing	Domestic stock grazing can potentially lead to pugging, selective plant removal, weed invasion, soil compaction, erosion and increased sediment and pollutants in rivers and wetlands. Grazing stock also compete for food with native animals and damage habitat (such as damaging invertebrate burrows because of soil compaction) (VEAC 2008). Grazing can result in habitat loss or modification, the introduction and spread of exotic plants as well as the inhibition of native vegetation establishment and growth, particularly seedlings. Damage to rivers and wetlands by grazing has also been demonstrated to affect habitat values for animals such as frogs and birds (VEAC 2008). Livestock grazing may also adversely affect soil structure, bed and bank stability, and water quality (VEAC 2008). Grazing can also reduce the capacity of riparian zone vegetation to act as a nutrient 'filter' by compacting the soil, increasing erosion and sediment input into waterways. These effects are strongest where grazing is continuous (VEAC 2008).	All

Appendix 6. Species lists

Fish

Scientific Name	Common Name	FFG	Vic Advisory	EPBC	Origin
Salmo trutta	Brown Trout				Introduced
Anguilla australis	Southern Shortfin Eel				
Oncorhynchus mykiss	Rainbow Trout				Introduced
Gadopsis marmoratus	River Blackfish				
Nannoperca australis	Southern Pygmy Perch				
Galaxias ornatus	Ornate Mountain Galaxias				
Galaxias truttaceus	Spotted Galaxias				
Prototroctes maraena	Australian Grayling	Listed	Vulnerable	Vulnerable	
Galaxias maculatus	Common Galaxias				
Galaxias brevipinnis	Climbing Galaxias				
Carassius auratus	Goldfish				Introduced
Pseudaphritis urvillii	Congolli				
Perca fluviatilis	Redfin				Introduced
Misc Dry	Dry waterbody				
Mordacia mordax	Shorthead Lamprey				
Gambusia holbrooki	Eastern Gambusia				Introduced
Macquaria australasica	Macquarie Perch	Listed	Endangered	Endangered	
Geotria australis	Pouched Lamprey				
Galaxiella pusilla	Dwarf Galaxis	Listed	Endangered	Vulnerable	
Misc No fish	No fish				
fam. Eleotridae gen. Hypseleotris	Carp Gudgeon				
cla. Petromyzontida ord. Petromyzontiformes	Lampreys				
ord. Tetraodontiformes fam. Aracanidae	Cowfish				

Scientific Name	Common Name	FFG	Vic Advisory	EPBC	Origin
Aldrichetta forsteri	Yellow-eye Mullet				
Cyprinus carpio	European Carp				Introduced
subf. Galaxiinae gen. Galaxias	Galaxias				
Galaxias olidus	Mountain Galaxias				
Philypnodon grandiceps	Flathead Gudgeon				
Afurcagobius tamarensis	Tamar Goby				
Anguilla reinhardtii	Longfin Eel				
Arenigobius bifrenatus	Bridled Goby				
Arripis trutta	Eastern Australian Salmon				
Maccullochella peelii	Murray Cod*	Listed	Vulnerable	Vulnerable	
Ophisurus serpens	Serpent Eel				

Mammals

Scientific Name	Common Name	FFG	Vic Advisory	EPBC	Origin
Pseudocheirus peregrinus	Common Ringtail Possum				
Petaurus australis	Yellow-bellied Glider				
Petauroides volans	Greater Glider		Vulnerable	Vulnerable	
Trichosurus cunninghami	Mountain Brushtail Possum				
Rattus fuscipes	Bush Rat				
Oryctolagus cuniculus	European Rabbit				Introduced
Vespadelus regulus	Southern Forest Bat				
Trichosurus vulpecula	Common Brushtail Possum				
Petaurus breviceps	Sugar Glider				
Miniopterus schreibersii GROUP	Common Bent-wing Bat	Listed			
Vombatus ursinus	Common Wombat				
Phascolarctos cinereus	Koala				
Chalinolobus morio	Chocolate Wattled Bat				

Scientific Name	Common Name	FFG	Vic Advisory	EPBC	Origin
Antechinus agilis	Agile Antechinus				
Rattus lutreolus	Swamp Rat				
Cervus unicolor	Sambar				Introduced
Ornithorhynchus anatinus	Platypus				
Tachyglossus aculeatus	Short-beaked Echidna				
Gymnobelideus leadbeateri	Leadbeater's Possum	Listed	Endangered	Critically Endangered	
Nyctophilus geoffroyi	Lesser Long-eared Bat				
fam. Dasyuridae gen. Antechinus	Antechinus				
Vulpes vulpes	Red Fox				Introduced
Vespadelus darlingtoni	Large Forest Bat				
Nyctophilus gouldi	Gould's Long-eared Bat				
Vespadelus vulturnus	Little Forest Bat				
Felis catus	Cat				Introduced
Antechinus swainsonii	Dusky Antechinus				
Wallabia bicolor	Black Wallaby				
Acrobates pygmaeus	Feathertail Glider				
Dasyurus maculatus maculatus	Spot-tailed Quoll	Listed	Endangered	Endangered	
Falsistrellus tasmaniensis	Eastern False Pipistrelle				
Mus musculus	House Mouse				Introduced
Canis lupus	Dingo & Dog (feral)				
Macropus giganteus	Eastern Grey Kangaroo				
Misc Target taxa not found	Target taxa not found				
Isoodon obesulus obesulus	Southern Brown Bandicoot	Listed	Near threatened	Endangered	
Rattus rattus	Black Rat				Introduced
fam. Macropodidae gen. Macropus	Kangaroo				
Perameles nasuta	Long-nosed Bandicoot				
Sminthopsis leucopus	White-footed Dunnart	Listed	Near threatened		
fam. Muridae gen.	Rats				

Scientific Name	Common Name	FFG	Vic Advisory	EPBC	Origin
Rattus					
Tadarida australis	White-striped Freetail Bat				
Lepus europeaus	European Hare				Introduced
Hydromys chrysogaster	Water Rat				
fam. Phalangeridae gen. Trichosurus	Brushtail Possums				
Mastacomys fuscus mordicus	Broad-toothed Rat	Listed	Endangered	Vulnerable	
supo. Laurasiatheria ord. Chiroptera	Bat				
fam. Peramelidae gen. Bandicoot	Bandicoots				
Antechinus minimus maritimus	Swamp Antechinus	Listed	Near threatened	Vulnerable	
Bos taurus	Cattle (feral)				Introduced
Cercartetus nanus	Eastern Pygmy-possum	Rejected	Near threatened		
Rattus norvegicus	Brown Rat				Introduced
Canis lupus familiaris	Dog				Introduced
Cervus dama	Fallow Deer				Introduced
Chalinolobus gouldii	Gould's Wattled Bat				

Bird species of high conservation value

Scientific Name	Common Name	FFG	Vic Advisory	EPBC	Treaty
Ardea modesta	Eastern Great Egret	Listed	Vulnerable		CAMBA JAMBA
Hirundapus caudacutus	White-throated Needletail		Vulnerable		CAMBA JAMBA ROKAMBA
Cinclosoma punctatum	Spotted Quail-thrush		Near threatened		
Ninox connivens connivens	Barking Owl	Listed	Endangered		
Biziura lobata	Musk Duck		Vulnerable		
Climacteris picumnus victoriae	Brown Treecreeper (south-eastern ssp.)		Near threatened		
Oxyura australis	Blue-billed Duck	Listed	Endangered		
Melanodryas cucullata cucullata	Hooded Robin	Listed	Near threatened		

Scientific Name	Common Name	FFG	Vic Advisory	EPBC	Treaty
Tyto tenebricosa tenebricosa	Sooty Owl	Listed	Vulnerable		
Accipiter novaehollandiae novaehollandiae	Grey Goshawk	Listed	Vulnerable		
Gallinago hardwickii	Latham's Snipe		Near threatened		BONNA2H CAMBA JAMBA,
Ninox strenua	Powerful Owl	Listed	Vulnerable		
Anas rhynchotis	Australasian Shoveler		Vulnerable		
Phalacrocorax varius	Pied Cormorant		Near threatened		
Plegadis falcinellus	Glossy Ibis		Near threatened		BONNA2S CAMBA
Nycticorax caledonicus hillii	Nankeen Night Heron		Near threatened		
Aythya australis	Hardhead		Vulnerable		
Alcedo azurea	Azure Kingfisher		Near threatened		
Calamanthus pyrrhopygius	Chestnut-rumped Heathwren	Listed	Vulnerable		
Tyto novaehollandiae novaehollandiae	Masked Owl	Listed	Endangered		
Lichenostomus melanops cassidix	Helmeted Honeyeater	Listed	Critically endangered	Endangered	
Lophoictinia isura	Square-tailed Kite	Listed	Vulnerable		
Platalea regia	Royal Spoonbill		Near threatened		
Botaurus poiciloptilus	Australasian Bittern	Listed	Endangered	Endangered	
Ardea intermedia	Intermediate Egret	Listed	Endangered		
Stictonetta naevosa	Freckled Duck	Listed	Endangered		
Numenius madagascariensis	Eastern Curlew		Vulnerable	Critically Endangered	BONNA1 CAMBA JAMBAR
Tringa nebularia	Common Greenshank		Vulnerable		BONNA2H CAMBA JAMBA
Hydroprogne caspia	Caspian Tern	Listed	Near threatened		CAMBA JAMBA
Egretta garzetta nigripes	Little Egret	Listed	Endangered		
Calidris ferruginea	Curlew Sandpiper		Endangered	Critically Endangered	BONNA2H CAMBA JAMBA
Ixobrychus flavicollis	Black Bittern	Listed	Vulnerable		

Scientific Name	Common Name	FFG	Vic Advisory	EPBC	Treaty
australis					

Invertebrates

Scientific Name	Common Name	FFG	Vic Advisory	EPBC	Origin
Engaeus cunicularius	Granular Burrowing Crayfish				
Engaeus quadrimanus	Lowland Burrowing Crayfish				
Engaeus hemicirratulus	Gippsland Burrowing Crayfish		Endangered		
Euastacus yarraensis	Southern Victorian Spiny Crayfish				
Euastacus kershawi	Gippsland Spiny Crayfish	Rejected			
Paratya australiensis	Common Freshwater Shrimp				
subo. Crassiclitellata supf. Megascolecoidea	Earthworms				
fam. Baetidae gen. Genus 2					
Euastacus woiwuru	Central Highlands Spiny Crayfish				
Hyridella drapeta	Freshwater Mussel				
Megascolides australis	Giant Gippsland Earthworm	Listed	Endangered	Vulnerable	
fam. Chironomidae subf. Orthocladiinae	Non-biting midge				
fam. Parastacidae gen. Engaeus	Burrowing Crayfish				
Simsonia wilsoni					
subf. Chironominae trib. Chironomini	Non-biting Midge				
supf. Unionoidea fam. Hyriidae	Freshwater Mussels				
Hyridella narracanensis	Narracan Freshwater Mussel				
Tipulidae SRV sp. 18	Crane fly				
supf. Rissooidea fam. Hydrobiidae	Mud snails				
supf. Leptoperloidea fam. Gripopterygidae	Stoneflies				

Scientific Name	Common Name	FFG	Vic Advisory	EPBC	Origin
subc. Micrura infc. Acarina	Mites and Ticks				
Engaeus sternalis	Warragul Burrowing Crayfish	Listed	Critically endangered		
Engaeus laevis	Richards Burrowing Crayfish				
Aphilorheithrus stepheni	Caddisfly				
fam. Parastacidae gen. Euastacus	Spiny Crayfish				
fam. Chironomidae subf. Tanypodinae	Non-biting midge				
supf. Tabanoidea fam. Athericidae	Water Snipe-flies				
supf. Chironomoidea fam. Thaumaleidae	Solitary midges				
Empididae SRV sp. 6	Dance Flies				
Ceratopogonidae SRV sp. 20	Biting Midges				
fam. Hydrobiosidae gen. Apsilochorema					
Tipulidae SRV sp. 25	Crane fly sp.				
fam. Hyriidae gen. Hyridella	Freshwater Hyridella Mussel				
Tipulidae EPA sp. 13	Crane fly sp.				
Tipulidae SRV sp. 37	Crane fly sp.				
fam. Parastacidae gen. Cherax	Yabby				
supf. Parastacoidea fam. Parastacidae	Freshwater Crayfishes				
fam. Chironomidae subf. Podonominae	Non-biting midge				
supf. Byrrhoidea fam. Elmidae	Riffle Beetles				
Tipulidae SRV sp. 28	Crane fly sp.				
Tipulidae EPA sp. 1					
Amarinus lacustris	Freshwater Spider Crab				
Cherax destructor destructor	Common Yabby				
Tipulidae SRV sp. 4					
fam. Glossosomatidae gen. Agapetus					
Engaeus urostrictus	Dandenong	Listed	Critically		

Scientific Name	Common Name	FFG	Vic Advisory	EPBC	Origin
	Burrowing Crayfish		endangered		

Plants of high conservation value

Scientific Name	Common Name	FFG	Vic Advisory	EPBC	Origin
Carex alsophila	Forest Sedge		Rare		
Leionema bilobum subsp. serrulatum	Toothed Leionema		Rare		
Lindsaea microphylla	Lacy Wedge-fern		Rare		
Burnettia cuneata	Lizard Orchid		Rare		
Eucalyptus strzeleckii	Strzelecki Gum	Listed	Vulnerable	Vulnerable	
Cephalomanes caudatum	Jungle Bristle-fern		Rare		
Adiantum diaphanum	Filmy Maidenhair	Listed	Endangered		
Correa reflexa var. lobata	Powelltown Correa		Rare		
Grevillea barklyana	Gully Grevillea	Listed	Vulnerable		
Persoonia arborea	Tree Geebung	Rejected	Vulnerable		
Lastreopsis hispida	Bristly Shield-fern		Rare		
Pittosporum undulatum subsp. X emmettii	Hybrid Pittosporum		Rare		Native but some stands may be alien
Astelia australiana	Tall Astelia	Listed	Vulnerable	Vulnerable	
Corybas aconitiflorus	Spurred Helmet-orchid		Rare		
Tetratheca stenocarpa	Long Pink-bells		Rare		
Tmesipteris parva	Small Fork-fern		Rare		
Billardiera scandens s.s.	Velvet Apple-berry		Rare		
Phebalium squamulosum subsp. squamulosum	Forest Phebalium		Rare		
Schoenus carsei	Wiry Bog-sedge		Rare		
Oxalis thompsoniae	Fluffy-fruit Wood-sorrel		Poorly known		
Caladenia flavovirens	Summer Spider-orchid		Rare		
Tmesipteris ovata	Oval Fork-fern		Rare		
Cardamine tenuifolia	Slender Bitter-cress		All ssp threatened		
Eucalyptus fulgens	Green Scentbark		Rare		
Desmodium varians	Slender Tick-trefoil		Poorly known		
Chiloglottis jeanesii	Mountain Bird-orchid		Rare		
Acacia leprosa var.	Large-leaf Cinnamon-		Rare		

Scientific Name	Common Name	FFG	Vic Advisory	EPBC	Origin
uninervia	wattle				
Pultenaea juniperina s.s.	Prickly Beauty		Rare		
Olearia asterotricha	Rough Daisy-bush		Rare		
Allocasuarina media	Prom Sheoak		Poorly known		
Pultenaea weindorferi	Swamp Bush-pea	Rejected	Rare		
Xanthosia leiophylla	Parsley Xanthosia		Rare		
Gahnia grandis	Brickmaker's Sedge		Vulnerable		
Bossiaea riparia	River Leafless Bossiaea		Rare		
Olearia speciosa	Netted Daisy-bush		Poorly known		
Sowerbaea juncea	Rush Lily		Rare		
Chorizandra australis	Southern Bristle-sedge		Poorly known		
Pterostylis chlorogramma	Green-striped Greenhood	Listed	Vulnerable	Vulnerable	
Eucalyptus yarraensis	Yarra Gum	Rejected	Rare		
Lepidium pseudohyssopifolium	Native Peppercress		Poorly known		
Lepidosperma canescens	Hoary Rapier-sedge		Rare		
Hakea dactyloides	Finger Hakea		Rare		
Cardamine tenuifolia (large-flower form)	Slender Bitter-cress		Endangered		

Appendix 7. Groundwater

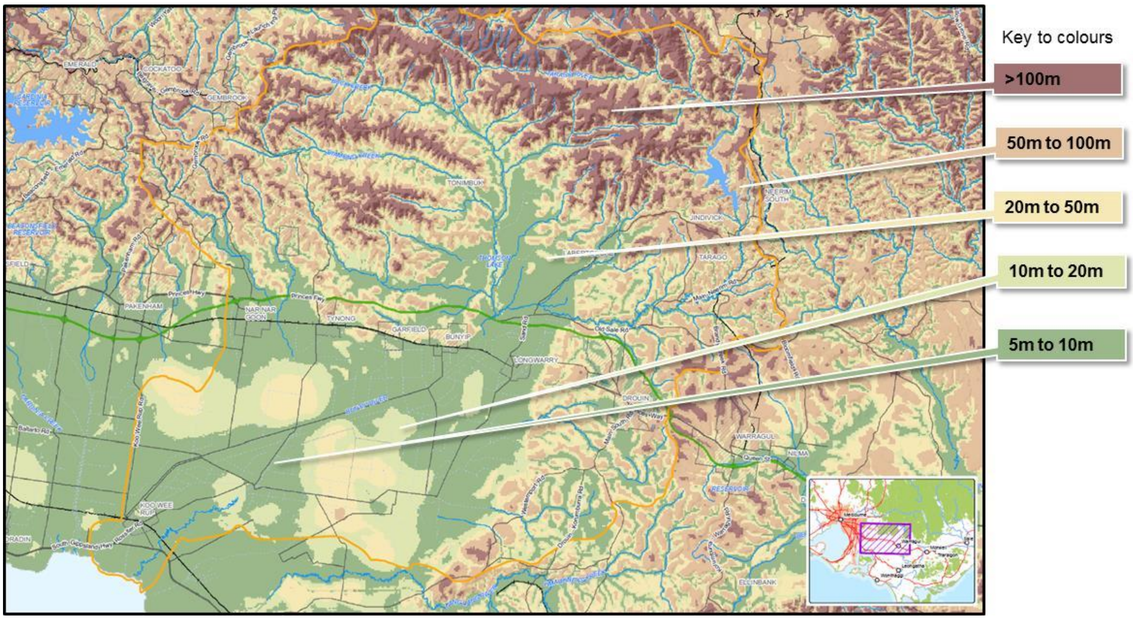


Figure 52 : Depth to the groundwater table

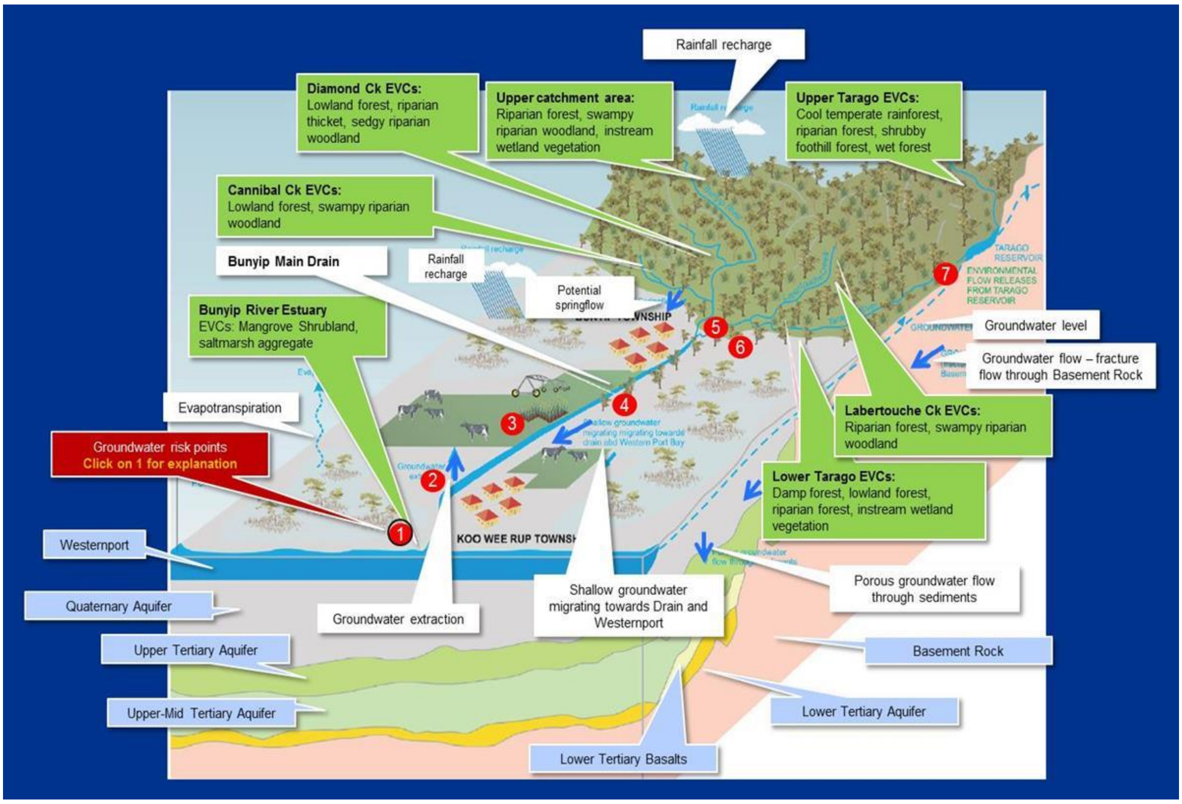


Figure 53 : Groundwater dependent ecosystems and risks and threats in the Tarago/Bunyip catchment

Explanation of Numbered Groundwater Risks:

1. Inland migration of saltwater-freshwater wedge due to groundwater pumping / Potential Seawater intrusion

2. Groundwater extraction inadvertently expanding the length of losing reaches
3. Artificial recharge due to irrigation / Poor groundwater and Surface Water Quality due to fertiliser application
4. Unqualified abstractions from stock/groundwater bores
5. Potential for salinity outbreaks
6. Surface water entitlement extraction
7. Reduced / decreased environmental flows during dry periods i.e. risk to baseflows downstream of Tarago Reservoir

Appendix 8. Ecological objectives and key flow components

Ecological objectives for fish

HWS objective	Ecological objectives and priority reaches	Ecological function	Expected response	Key flow component	Timing
Upper Bunyip and Tarago - Maintain high species richness and abundance of fish populations	**Maintain self-sustaining populations of River Blackfish and Mountain Galaxias** **Reach 1**	**River Blackfish**	Provision of deep pools suitable for cover protection from birds of prey and overheating of pools in Summer	Low Flow	All year
		Mountain Galaxias	Provision of pool with adequate depth to support fish species	Low Flow	All year
		Habitat maintenance	Maintenance of pool habitat, undercut banks, riffles and debris accumulations	Low Flow Fresh	Dec - May
		Localised movement of resident fish	Provision of suitable fish passage over riffles and runs with suitable depth of cover	Low Flow Fresh	Dec - May
			Provision of suitable fish passage over riffles and runs with suitable depth of cover	High Flow	Jun - Nov
		Juvenile fish habitat	Inundate marginal habitats to create suitable habitat	High Flow	Oct - Nov (late High Flow Season)
		Habitat maintenance	Maintenance of fish habitat	High Flow Fresh	Jun - Nov
	Maintain the full suite of native migratory and non-migratory fish species, and increase the abundance of native fish within the reach **Reach 2, 4**	**Habitat availability for River Blackfish**	Provision of deep pools suitable for cover protection from birds of prey and overheating of pools in summer	Low Flow	All year
		Habitat availability for Australian Grayling		Low Flow	All year

HWS objective	Ecological objectives and priority reaches	Ecological function	Expected response	Key flow component	Timing
		Habitat availability for small-bodied fish	Provision of pool with adequate depth to support fish species	Low Flow	All year
		Habitat maintenance	Maintenance of fish habitat	Low Flow Fresh High flow fresh	Dec – May Jun - Nov
		Localised movement of resident fish	Provision of suitable fish passage over riffles and runs with suitable depth of cover	Low Flow Fresh High Flow	Dec – May Jun - Nov
		Spawning trigger for downstream dispersal of Australian Grayling	Successful reproduction of Australian Grayling	Low Flow Fresh	April - May
		Inundate marginal habitats for juvenile fish	Creation of habitat necessary for successful recruitment of resident species	High Flow	Oct - Nov (late High Flow Season)
		Upstream migration trigger for Australian Grayling	Successful reproduction of Australian Grayling	High Flow Fresh	Oct - Nov
		Upstream migration of Australian Grayling	Successful movement from estuary to the river	High Flow	Oct - Nov
		Upstream migration of small bodied migratory fish	For successful reproduction of small bodied migratory fish populations	High Flow	Oct - Nov
Lower Bunyip - Works aim to maintain condition over the next 20 years.	**Maintain passage for migratory fish moving between the estuary and the upper reaches** **Reach 6**	**Upstream migration of Australian Grayling from estuary to the river**	Successful reproduction of Australian Grayling	High Flow	Oct - Nov (late High Flow Season)
		Upstream migration of small bodied migratory fish	For successful reproduction of small bodied migratory fish populations	High Flow	Oct - Nov (late High Flow Season)

Ecological objectives for vegetation

HWS objective	Ecological objectives and priority reaches	Ecological function	Expected response	Key flow component	Timing
Upper Bunyip and Tarago - Works over the next 20 years aim to improve condition from moderate to high	**Maintain high quality riparian vegetation** Reach 1	**Habitat inundation variability to provide zonation**	Successful establishment and reproduction of a range of riparian species throughout the riparian zone	High Flow Fresh Bankfull	Any time
		Habitat inundation	Provision of moisture to benches	High Flow	Jun - Nov
		Habitat inundation	Provision of moisture to floodplain	Overbank	Jun - Nov
		Prolonged inundation of bank, bench and bars	Prevention of vegetation encroachment in riparian zone	High Flow	Jun - Nov
		Riparian disturbance and propagule distribution	For successful recruitment of riparian species	Overbank	Any time
		Habitat inundation / regeneration	Continued sediment supply to benches to maintain good habitat for riparian vegetation	High Flow Fresh	Any time
		Maintain aquatic vegetation in channel	Healthy populations of in-stream vegetation	Low Flow	Dec - May
		Prevent encroachment on vegetated bar	Disturbance of vegetation species living on in-stream bars to prevent overcrowding	Low Flow Fresh	Dec - May
	Maintain the health of remnant riparian vegetation and provide flow conditions to encourage diverse riparian regeneration Reach 2	**Habitat inundation variability to provide zonation**	Successful establishment and reproduction of a range of riparian species throughout the riparian zone	High Flow Fresh Bankfull	Any time
		Habitat inundation	Provision of moisture to benches	High Flow	Jun - Nov
		Habitat inundation	Provision of moisture to floodplain	Overbank	Jun - Nov
		Prolonged inundation of bank, bench and bars	Prevention of vegetation encroachment in riparian zone	High Flow	Jun - Nov

HWS objective	Ecological objectives and priority reaches	Ecological function	Expected response	Key flow component	Timing
		Riparian disturbance and propagule distribution	For successful recruitment of riparian species	High Flow Bankfull	Any time Jun - Nov
		Habitat inundation / regeneration	Continued sediment supply to benches to maintain good habitat for riparian vegetation	High Flow Fresh	Any time
		Maintain aquatic vegetation in channel	For healthy populations of in-stream vegetation	Low Flow	Dec - May
		Prevent encroachment on vegetation to sand bars	Disturbance of vegetation species living on in-stream bars to prevent overcrowding	Low Flow Fresh	Dec - May
	Provide flows to prevent the decline in riparian condition and contraction of the riparian zone Reach 4	**Habitat inundation variability to provide zonation**	Successful establishment and reproduction of a range of riparian species throughout the riparian zone	High Flow Fresh Bankfull	Any time
		Habitat inundation	Provision of moisture to benches	High Flow	Jun - Nov
		Habitat inundation	Provision of moisture to floodplain	Overbank	Jun - Nov
		Prolonged inundation of bank, bench and bars	Prevention of vegetation encroachment in riparian zone	High Flow	Jun - Nov
		Riparian disturbance and propagule distribution	For successful recruitment of riparian species	Overbank	Any time
		Maintain aquatic vegetation in channel	Healthy populations of in-stream vegetation	Low Flow Low Flow Fresh	Dec - May
Lower Bunyip - Works concentrating on streamside revegetation will aim to improve condition to moderate over the next 20 years	**Maintain health and improve the diversity of lower bank riparian vegetation** Reach 6	**Habitat inundation**	Successful establishment and reproduction of some riparian species in the lower riparian zone	Low Flow Fresh	Any time
		Maintain aquatic vegetation in channel	Healthy populations of in-stream vegetation	Low Flow	Dec - May

Ecological objectives for macroinvertebrates

HWS objective	Ecological objectives and priority reaches	Ecological function	Expected response	Key flow component	Timing
Upper Bunyip and Tarago -Works to protect and improve water quality and habitat aim to raise this condition from high to very high in the next 20 years	**Maintain excellent condition macroinvertebrate communities** **Reach 1, 2, 4**	**Bed habitat availability**	Provision of habitat to wide diversity of macroinvertebrate types	Low Flow High Flow	Dec – May Jun - Nov
		Edge habitat availability	Provision of habitat to wide diversity of macroinvertebrate types	Low Flow	Dec - May
		Water quality maintenance	Re-oxygenation of water and flushing of nutrients out of pools	Low Flow	Dec - May
		Refresh water quality and flush habitat	Re-oxygenation of water, introduction of carbon and nutrients. Scour and regeneration of macroinvertebrate community.	Low Flow Fresh	Dec - May
		Habitat maintenance	Removal of sediments and biofilm from woody debris to enhance habitat value of instream habitat (eg submerged logs)	Low Flow Fresh High Flow Fresh	Dec – May Jun - Nov
		Movement of bed material to maintain bed diversity	Mobilisation of sand to maintain and create a diversity of habitats	High Flow Fresh	Jun - Nov
		Entrain terrestrial carbon to the stream	Provision of food source to macroinvertebrate community	High Flow Fresh Overbank Flow	Jun - Nov
Lower Bunyip - Improvements aim to improve condition from moderate to high within the next 20 years	**Maintain excellent condition macroinvertebrate community** **Reach 6**	**Edge habitat availability**	Provision of habitat to wide diversity of macroinvertebrate types	Low Flow High Flow	Dec – May Jun - Nov
		Habitat maintenance	Removal of sediments and biofilm from available habitats	Low Flow Fresh High Flow Fresh	Dec – May Jun - Nov
		Water quality maintenance	Re-oxygenation of water and flushing of nutrients out of pools	Low Flow	Dec - May

Ecological objectives for platypus

HWS objective	Ecological objectives and priority reaches	Ecological function	Expected response	Key flow component	Timing
Works aim to stabilise this population to allow for improvement over the long term.	Maintain flow conditions suitable for Platypus Reach 6	**Habitat availability**	Maintaining sufficient water level to inundate habitat for Platypus	Low Flow High Flow	Dec – May Jun - Nov
		Habitat maintenance	Removal of sediments and biofilm from available habitats	Low Flow Fresh High Flow Fresh	Dec – May Jun - Nov
		Water quality maintenance	Re-oxygenation of water and flushing of nutrients out of pools	Low Flow	Dec - May

Ecological objectives for frogs, birds and amenity

HWS objective	Ecological objectives and priority reaches	Ecological functions and expected response	Key flow component	Timing
Frogs: • Improve condition to high over the next 20 years through improvements in floodplain habitat (Upper Bunyip and Tarago) • Maintaining high condition over the next 20 years and beyond will be the focus of floodplain works (Lower Bunyip)	Not determined in Flows Studies	Maintain pools with an adequate depth of water for habitat for macroinvertebrates, an important food source for birds and frogs	Low Flow	Summer / Autumn
		Provides disturbance to scour the riverbed of sediment and improve the quality of instream habitat	Low Flow Fresh	
		Provides a suitable depth of water for birds, maintaining the extent of habitat they can utilise		
		Provides flow variability to maintain a diversity of emergent and riparian vegetation and helps to influence vegetation zonation patterns across the channel, providing a variety of habitats		
Birds: • Maintain moderate condition over the next 20 years with improvements in the longer term (Upper Bunyip and		Moves sediment along the river, improving the quality of, and access to, instream habitat	High Flow	Winter / Spring
		Sustains longitudinal connectivity, providing opportunities to move along and between habitats		

HWS objective	Ecological objectives and priority reaches	Ecological functions and expected response	Key flow component	Timing
Tarago) • The number and variety of species is very low. Works to improve habitat aim to raise this condition to low over 20 years and moderate in the long term (Lower Bunyip) **Amenity**: • Maintain high amenity values (Upper Bunyip and Tarago) • Actions targeted at improving vegetation will increase the condition to moderate in the long term, but the small amount of public land and limited access to waterways will restrict the overall gain possible (Lower Bunyip)		Influences vegetation zonation pattern across the channel, providing a variety of habitats		
		Entrain terrestrial carbon to the stream - Provision of food source to macroinvertebrate community	High Flow Fresh	
		Habitat inundation/regeneration – provision of moisture and sediment to benches		
		Mobilisation of sand to maintain and create a diversity of habitats		
		Habitat inundation – variability to provide zonation and successful establishment and reproduction of a range of riparian species throughout the riparian zone	Bankfull	
		Riparian disturbance and propagule distribution - Successful recruitment of riparian species		
		Habitat inundation – provision of moisture to floodplain	Overbank Flows	
		Entrain terrestrial carbon to the stream - Provision of food source to macroinvertebrate communities		

Preliminary ecological objectives for Bunyip estuary

Ecological objectives	Ecological function	Flow Recommendation
Maintaining connectivity with the upper catchment	A flow of 70 ML/d is likely to maintain a depth of water in the estuary of 15cm. This is considered a minimum for fish passage.	Minimum flow of 70 ML/d should be maintained in the estuary in all seasons unless low flows fall naturally below this
Provide channel forming flows and mobilisation of sediment	Channel forming flows set for Reach 6 are considered appropriate for the estuary.	Higher flows (> 1500ML/d) should occur at the frequency specified for Reach 6 (once every 2 years)

Ecological objectives	Ecological function	Flow Recommendation
	Smaller flood flows (freshes) are required to aid in sediment removal from the estuary and to increase the frequency of inundation of fringing salt marsh and salt scrub communities in the lower estuary.	As an interim flow regime the frequency of freshes recommended for Reach 6 under both high and low flow conditions should be adopted for the estuary: • Low flow: 3 freshes of 120ML/d over 7 days • High flow: 3 freshes of 170ML/d over 2 days

Flow recommendations in response to ecological objectives

Reach	Low Flow	Low Flow Fresh	High Flow	High Flow Fresh	Bankfull	Overbank	Channel Maintenance Flow
1	>10ML/d – or natural (Dec-May)	35ML/d (5/yr, 4d – or natural)	35ML/d – or natural (Jun-Nov)	120ML/d (3/yr, 2d – or natural)	200ML/d (2/yr, 2d – or natural)	300ML/d (1/yr, 1d – or natural)	Not specified
2	>12ML/d – or natural (Dec - May)	100ML/d (5/yr, 4d – or natural) (Dec – May) 200ML/d (1/yr, 1d – or natural) (Apr – May)	100ML/d – or natural (Jun-Nov)	280ML/d (4/yr, 3d incl. 1 event in late Oct-Nov – or natural)	600ML/d (1/yr, 1d – or natural)	1000ML/d (1 in 2 years, 1d – or natural)	1000ML/d (1 in 2 years, 1d – or natural)
3	Not provided						
4	>10ML/d – or natural (Dec-May)	22ML/d (5/yr, 4d – or natural) 175ML/d (1/yr, 1d - or natural)	22ML/d – or natural (Jun-Nov)	70ML/d (4/yr, 3d including 1 in late Oct-Nov – or natural)	100ML/d (4/yr, 3d– or natural)	200ML/d (2/yr, 3d– or natural)	Not specified
5	Not provided						
6	50ML/d – or natural (Dec-May)	120ML/d (3/yr, 7d – or natural)	50ML/d – or natural (Jun-Nov)	170ML/d (3/yr, 2d including 1 in Nov – or natural)	Not specified	Not specified	1500ML/d (1 in 2 years, 1d – or natural)

Reach	Low Flow	Low Flow Fresh	High Flow	High Flow Fresh	Bankfull	Overbank	Channel Maintenance Flow
			70ML/d – or natural (Oct-Nov)				
7	70ML/day (or natural) (Dec – May)	120ML/d (3/yr, 7d – or natural)	70ML/d – or natural (Oct-Nov)	170ML/d (3/yr, 2d including 1 in Nov – or natural)	Not specified	Not specified	1500ML/d (1 in 2 years, 1d – or natural)
1	>10ML/d – or natural (Dec-May)	35ML/d (5/yr, 4d – or natural)	35ML/d – or natural (Jun-Nov)	120ML/d (3/yr, 2d – or natural)	200ML/d (2/yr, 2d – or natural)	300ML/d (1/yr, 1d – or natural)	Not specified
Ecological objectives	Habitat availability (River Blackfish) – Depth availability and sufficient area	Inundation of vegetated bar – prevent vegetation encroachment into the stream	Inundation of banks, benches and bars to disadvantage terrestrial species	Prevent encroachment of terrestrial vegetation and maintain flood tolerant species	To encourage flood tolerant vegetation	Inundate floodplain habitats and relocate propagules or create regeneration niches	N/A

Appendix 9. Detailed Risk Assessment

Risk Category	Values Impacted	Likelihood	Consequence	Risk	Management Actions	Residual Risk after Management Actions
RISKS TO ACHIEVING ECOLOGICAL OBJECTIVES						
Further consumptive extraction of surface water, causing an alteration of natural flow regimes	All	Possible	Major	High	• A cap has been placed on surface water extractions in the Tarago/Bunyip catchment, preventing extraction over and above limits set through water entitlements. • Government regularly reviews surface water sustainable diversion limits in Victoria in light of antecedent catchment and climate conditions, additional environmental flows knowledge, and water demand. • Residual risk is calculated based on the assumption that likelihood is reduced to 'Unlikely' following intervention actions.	Medium
Groundwater extractions causing shifts in the surface water/groundwater interface	All	Possible	Moderate	Medium	• A cap on the volume of groundwater extractions exists in the catchment through licenced groundwater entitlements, which limit the amount of groundwater that can be taken each year. These extraction limits are reviewed regularly to ensure their continuing effectiveness and sustainability. • Residual risk is calculated based on assumption that the likelihood is reduced to 'Unlikely' and consequences are reduced to 'Moderate' following intervention actions.	Low
Construction of additional artificial instream structures (e.g. dams, weirs, gauging stations)	All	Unlikely	Major	High	• Melbourne Water will work with State Government to influence the design of any potential new water storage and conveyance infrastructure such that it is sensitive to habitat connectivity and quality needs (e.g. fish passage, temperature) and is able to be managed for environmental flow regime requirements. • Residual risk is calculated based on the	Medium

Risk Category	Values Impacted	Likelihood	Consequence	Risk	Management Actions	Residual Risk after Management Actions
					assumption that management actions reduce the consequence to 'Moderate'	
Recreational fishing	Fish	Almost Certain	Moderate	High	• In partnership with VRFish, Melbourne Water will develop and implement an education and involvement program with recreational fishing groups to ensure native fish are released but introduced fish are not released back in to the river. • Residual risk has assumed that the likelihood is reduced to 'Possible' following intervention actions.	Medium
Land use change – Urban Development	Vegetation Geomorphology Fish Platypus	Likely	Moderate	High	• Under its Waterways Operating Charter, Melbourne Water is obligated to ensure urban development achieves appropriate standards of flood protection, protects waterway health and is sensitive to other environmental and social values of waterways. • Local government is a key player in the success of managing the impacts of urban development because of its role and responsibilities in land use planning, drainage management, management of development, rates, and a variety of services including road infrastructure development and maintenance, water supply and the disposal of wastewater. • Melbourne Water will work in collaboration with DELWP, and relevant Local Councils to understand and reduce the risks of increasing urban development • Melbourne Water is also investigating options for stormwater harvesting and reuse for environmental flows through Water Sensitive Urban Design and integrated water cycle management programs • Residual risk is assessed assuming that the consequences of urban development can be ameliorated to 'Moderate' through management actions	Medium

Risk Category	Values Impacted	Likelihood	Consequence	Risk	Management Actions	Residual Risk after Management Actions
Pest plants and animals: • Pest fish • Foxes, dogs and cats • Deer • Willows	All	Almost certain	Moderate	High	• Actions for the broad scale control of carp are yet to prove successful. The proposed flow regime for the river may indeed provide favourable conditions for Carp. • Physical removal of Gambusia before the species' spawning season can result in major reductions in its abundance, even resulting in complete eradication at some sites. The degree of success depends on site hydrology and hydrological connectivity, ecological value, habitat complexity, habitat size and climate. • Fox control programs may assist in reducing the likelihood of fox predation, as may improving riparian vegetation cover and longitudinal connectivity along the river. • Residual risk is calculated based on the assumption that management interventions have reduced the likelihood to 'Possible'.	Medium
Illegal fishing nets	Platypus Fish Birds	Almost certain	Major	Extreme	• A vigorous community education campaign, particularly targeting school groups, is the most effective method to address these issues using resources such as platypusSPOT, media, community talks and signage around waterways. • Residual risk is based on the assumption that the likelihood of the risk occurring is reduced.	Medium
Sediment inputs to the estuary and Western Port	Fish Vegetation	Almost certain	Moderate	High	• Working in collaboration with Local Councils and Port Phillip and Westernport CMA for catchment wide erosion control and mitigation programs will assist in ameliorating this risk. • Stormwater capture and treatment options through Water Sensitive Urban Design projects and Integrated Water Cycle Management Plans and programs will also help to reduce sedimentation issues within the waterway and estuary. • Residual risk is based on the assumption that likelihood is reduced to 'Possible' following	Medium

Risk Category	Values Impacted	Likelihood	Consequence	Risk	Management Actions	Residual Risk after Management Actions
					management interventions.	
Further expansion of irrigation areas within the catchment	All	Unlikely	Major	High	• Adaptive management, sourcing alternative supplies of water through Integrated Water Cycle Management plans, and monitoring of current water availability, will assist in understanding water availability and Sustainable Diversion Limits. • Residual risk is based on the assumption that the consequences of irrigation expansion can be reduced.	Medium
Stock access and grazing pressure	Vegetation Fish Platypus Amenity	Certain	Moderate	High	• Catchment and river health programs through the Melbourne Water Healthy Waterways Strategy will help to reduce the likelihood of this risk occurring. Removing stock access to waterways within the catchment is a strategic priority for the HWS. • Residual risk is based on the assumption that management interventions reduce the likelihood of this risk occurring.	Medium
Climate Change	All	Almost certain	Extreme	Extreme	• Management actions will focus on understanding the nature of the risks that climate change poses to the biodiversity and ecosystem services of the Tarago/Bunyip system and catchment. • Programs to improve the resilience of water-dependent environmental values will be implemented. Planning for environmental flow releases will take in to consideration the relative vulnerabilities and sensitivities of high value species to climate change stressors. • Residual risk is based on the assumption that the consequences of climate change will be difficult to mitigate given the volumetric limitations of the current Environmental Entitlement.	High
OPERATIONAL RISK AS A RESULT OF RELEASING FLOWS						

Risk Category	Values Impacted	Likelihood	Consequence	Risk	Management Actions	Residual Risk after Management Actions
Winter high fresh drowns juvenile platypus	Platypus	Possible	Major	High	• Deliver winter high fresh in August to trigger females to select or construct nursery burrows higher up the river bank	Low
Environmental flow releases lead to safety risks to river users	N/A	Rare	Extreme	High	• Release plans to include controlled/gradual increases in flow rates. • Undertake appropriate communications actions to alert users, especially for high use sites and high use periods	Low
Release volume is insufficient in meeting required flow at target point	All	Possible	Moderate	Medium	• To date, orders have generally been slightly higher than required to ensure compliance. • Close communication with storage operators and monitoring of losses is increasing the required body of knowledge	Low
Current recommendations on environmental flow are inaccurate	All	Possible	Moderate	Medium	• Flow recommendations are based on the best possible science and a monitoring program is in place to identify if ecological objectives are not being achieved. A systematic review of recommendations was conducted in 2013.	L
Storage Operator maintenance works affect ability to deliver water	All	Possible	Moderate	Medium	• Undertake early planning and communications with Storage Operator to minimise likelihood of constraints and enable scheduling of maintenance outside of high demand periods.	L
Resource Manager cannot deliver required volume or flow rate (outlet/capacity constraints, insufficient storage volume) OR Competing storage operator priorities for flood and fire management do not allow delivery of some events	All	Possible	Moderate	Medium	• Undertake early planning and communications with Storage Operator to minimise likelihood of constraints and enable scheduling of maintenance outside of high demand periods. • Coordination with storage manager has avoided this in the past by changed scheduling of delivery.	Low

Risk Category	Values Impacted	Likelihood	Consequence	Risk	Management Actions	Residual Risk after Management Actions
Releases cause water quality issues (e.g. blackwater, low DO, mobilisation of saline pools, acid-sulphate soils, etc)	All	Possible	Moderate	Medium	• Monitor water quality in the lead up to and during events and adjust release plans as necessary based on data provided by Storage Operator • Undertake research to identify risk factors and triggers	Low
Improved conditions for non-native species (e.g. carp)	Fish	Unlikely	Minor	Low	• No effective mitigation actions currently possible	Low
Unable to provide evidence that hydrological target has been met	All	Possible	Minor	Low	• Stream flow gauging is adequate.	Low
Environmental releases do not achieve planned/specified flow targets due to releases being diverted by other users before reaching delivery sites	All	Possible	Moderate	Medium	• Ensure diversions field staff are aware of planned events and are managing compliance with orders by all users • Ensure diversions field staff are aware of planned events and are managing compliance with orders by all users.	Low
Environmental releases cause unauthorised inundation of private land, resulting in impacts on landowner activities and assets	Amenity	Unlikely	Major	High	• Development of release plans designed to avoid overbank flows • Monitoring of events and adjustment of releases to avoid overbank flows	Low
Environmental release interferes with essential Melbourne Water services	N/A	Unlikely	Moderate	Low	• Regular communication has been established with MW River Health and Maintenance teams and potential risk to delivery of works has been rated as low at a general level. • Teams are notified prior to all releases.	L
Inability to demonstrate outcomes achieved through environmental watering activities lead to a loss of public/political support	All	Likely	Moderate	High	• Monitor flow deliveries and share / communicate outcomes. • Communicate benefits of environmental watering to the broader community • Undertake investigations and research into flow relationships across multiple systems and	Low

Risk Category	Values Impacted	Likelihood	Consequence	Risk	Management Actions	Residual Risk after Management Actions
					translate into improved knowledge	
The environmental water account is overdrawn, leading to water not being available as per approved watering statement to complete planned actions	All	Rare	Minor	Low	• Monitor account balances and undertake regular communications with waterway manager as part of portfolio management activities	Low
Community concern over environmental releases under dry seasonal conditions may lead to a loss of support for environmental watering activities	All	Possible	Minor	Low	• Communicate benefits of environmental watering ot the boarder community and provide information on water entitlements framework	Low
Public misperception of the purpose of releases	All	Possible	Moderate	Medium	• An email list of interested parties has been created and updates on planned watering occur regularly. • Interest from agencies and public enquiries indicates a reasonably widespread level of community interest and support. • VEWH has a communications strategy to promote the benefits of environmental watering	Low