Seasonal Watering Proposal 2023-2024

Lower Broken Creek

GOULBURN BROKEN CATCHMENT MANAGEMENT AUTHORITY

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Front cover photo: Lower Broken Creek, looking west from Walshes Bridge during spring flooding (Pam Beattie, 2 November 2022)

It should be noted that specific reference to funding levels in this document are for indicative purposes only. The level of Government investment in this plan is contingent on budgets and government priorities.

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Executive Summary

This proposal identifies the environmental water requirements of the lower Broken and Nine Mile Creeks in 2023-24, to maintain or improve their ecological health. The proposal is based on the FLOWS study completed in 2019.

Along with their floodplain and wetland habitats, the lower Broken and Nine Mile Creeks are culturally significant to the Yorta Yorta Traditional Owners. They support a diverse and abundant native fish community, provide water for agriculture and urban centres, and facilitate a variety of recreational activities. The Broken Creek is a priority waterway in the Goulburn Broken Waterway Strategy 2014-2022 and the floodplain of the lower Broken and Nine Mile Creeks is listed in the 'Directory of Important Wetlands in Australia' (Environment Australia 2001). Stretches of the Broken and Nine Mile Creeks have been reserved as State Park and Natural Features Reserve.

Delivery of environmental water aims to work towards the following long-term environmental objectives:

Table A: Environmental objectives for the lower Broken and Nine Mile Creeks

Ecological value	Long-term environmental objective
Native fish	1. Increase native fish abundance including the threatened Murray cod, golden perch and silver perch.
Native aquatic fauna	2. Maintain platypus, Rakali (water rat) and turtle populations, particularly outside the irrigation season.
Native vegetation	3. Avoid excessive build-up of *Azolla*. 4. Maintain and promote the cover and condition of native instream and littoral vegetation communities.
Macroinvertebrates	5. Maintain and promote the diversity and abundance of macroinvertebrates.
Water quality	6. Maintain dissolved oxygen levels suitable for aquatic animals.

Three potential watering actions contribute towards achieving these objectives and include:

- Winter low flows – to maintain instream habitat and connectivity year-round, as well as reduce stagnation of water in weir pools.
- Spring/summer/autumn low flows – to increase the availability of instream habitat, provide cues for fish movement/spawning, mobilise *Azolla* accumulations, maintain suitable dissolved oxygen levels and support the growth of native vegetation in the littoral zone.
- Freshes – to cue native fish movement into the system from the Murray River and flush large *Azolla* accumulations.

These watering actions are relevant to each climate scenario, as the environmental flow needs of the creeks is largely independent of annual climatic conditions. Catchment runoff may contribute to winter low flows and *Azolla* flushing flows in wet periods, but most water is sourced from the Murray and Goulburn Rivers. It is instead the variable flow needs of *Azolla* and dissolved oxygen management throughout the year, that determines how flows are adaptively managed. These watering actions are therefore proposed as follows in 2023-24:

Table B: Potential watering actions 2023-24

Tier	Flow component	Expected watering effects	Climate scenario			
			Extreme dry	Dry	Average	Wet
1	Winter low flow: 40 ML/d continuously, May to August	Provide year-round habitat and instream refuge areas for native fauna. Improve platypus carrying capacity and reduce predation risk. Minimise exposure of turtles during winter dormancy. Maintain longitudinal connectivity to allow instream fauna to access food and shelter. Maintain inundation of instream aquatic plants, so they persist and provide food and cover for native fauna. Reduce stagnation of water in weir pools.	•	•	•	•
1	Spring/summer/autumn low flow: 200-450 ML/d continuously, August to May	Increase availability of instream habitat for native fauna. Increase flow cues for fish movement and spawning. Provide soil moisture to improve the establishment and growth of native littoral vegetation. Inundate benches to promote the growth of instream aquatic species. Increase mobilisation of *Azolla* accumulations. Reduce stagnation of water in weir pools. Maintain dissolved oxygen levels over summer.	•	•	•	•
1	Freshes: 1 to 3 events of 300-450 ML/d for 1-2 weeks, July-November	As per "spring/summer/autumn low flow" above. Note: flow over 300 ML/d can flush *Azolla* whilst it is still in single layers or individual plants. Flushes up to 450 ML/d disperse large blooms.	•	•	•	•*

Note: only potential watering actions for reaches 3 and 4 are shown in the table. Potential watering actions for all 4 reaches are described in the body of this report. * Freshes are likely to be met by unregulated flows under a wet scenario, but may still be required depending on the timing and extent of unregulated flows and the presence of *Azolla* accumulations.

The potential watering actions for 2023-24 may be subject to change if research and scientific advice due in mid 2023 suggests amendments would lead to improved environmental outcomes. Any changes would be discussed with key stakeholders and require approval from the VEWH prior to implementation.

If delivered in full, the above proposal requires approximately 91,100ML of water. If IVT and Murray Bypass deliveries occur through the lower Broken and Nine Mile Creeks this coming year, the volume of environmental water required to meet the flow targets will likely reduce to less than 50,000 ML. Prior to 2021-22, annual environmental water deliveries ranged between 30,000 and 43,000 ML. In the absence of water-in-transit deliveries years such as 2021-22, environmental water deliveries were closer to 70,000 ML.

The above watering actions were achieved in 2022-23 to varying degrees. Winter low flows could not be delivered due to maintenance works on the channel network. Fish ladders were closed during this time to retain refuge habitat during the low flow conditions, which included minor unregulated inflows. Environmental water was delivered for a short time at the start of the irrigation season to provide spring low flows, before large unregulated inflows and natural flooding occurred over October and November (far exceeding any spring fresh flow targets). Goulburn Water Quality Reserve was delivered from select outfalls between the spring flood events to provide water quality refuge habitat from the hypoxic blackwater conditions. Environmental water deliveries commenced in summer after the floods to provide low flows, which helped restore and maintain water quality more broadly across the system. Given the very wet conditions, no IVT or Murray bypass deliveries were called by the MDBA in 2022-23.

The greatest risks to successful delivery of environmental water in the lower Broken and Nine Mile creeks in 2023-24 are the ongoing capacity constraints within the irrigation channel network, especially during periods of high irrigation demand, and the need for infrastructure maintenance during the off-irrigation season. Both of these risks have the potential to prevent or reduce the delivery of environmental flows at certain times. The GBCMA and GMW will work closely together to optimise deliveries of environmental water around these constraints.

Once flows are delivered, the ability to fully achieve the environmental outcomes being sought is hindered in part by the highly regulated nature of the system and the poor instream habitat in some locations. Goulburn Broken CMA will continue to identify opportunities for complementary works that improve the health of the creek and enhance the outcomes from environmental water deliveries.

This proposal does not take account competing needs for environmental water use from other river/creek systems or downstream along the Murray River. However, environmental water deployed in the lower Broken and Nine Mile Creeks returns to the Murray River and is available for use downstream. As all of the flows proposed are well within the channel of the creeks, there is a very low risk of adverse impacts to private assets from releasing environmental water.

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Glossary and acronyms

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

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

Catchment Management Authority (CMA) - statutory authorities established to manage regional and catchment planning, waterways, floodplains, salinity and water quality.

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

Commonwealth Environmental Water Office (CEWO) - (part of the Department of the Environment and Energy) holds and manages the water entitlements purchased through the Restoring the Balance water recovery program.

Department of Energy, Environment and Climate Action (DEECA) (previously the Department of Environment, Land, Water and Planning, DELWP) – Victorian government department responsible for protecting the environment and responding to climate change.

DO - dissolved oxygen level of water.

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

Environmental flow study - a scientific study of the flow requirements of a particular waterway or wetland used to inform management decisions and allocation of water resources.

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

Flow - movement downstream of water confined in the waterway channel.

Flow component - components of a river system's flow regime that can be described by timing, seasonality, frequency and duration (for example, cease to flow and overbank flows).

Flow regime - pattern of seasonal flow variations in any one year, usually consisting of periods of low flow during summer-autumn then high flows during winter-spring.

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

GB CMA - Goulburn Broken Catchment Management Authority.

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

Gigalitre (GL) - one billion (1,000,000,000) litres.

GMW – Goulburn-Murray Rural Water Corporation, trading as Goulburn-Murray Water.

High flows - high flow within channel capacity. High flows allow full connection between all habitats in the river, which is important to fish passage during migration.

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

Instream - refers to that area of a waterway below the surface of the water.

Inter-Valley Transfers (IVT) - means bulk transfers of water from the Goulburn water supply system to supply water users in the Murray water supply system.

Lotic – flowing or moving water.

Low reliability entitlement - legally recognised, secure entitlement to a defined share of water, as governed by the reserve

policy (full allocations are expected only in some years).

Macroinvertebrates - aquatic invertebrates whose body length usually exceeds 1 mm (includes insects, crustaceans, aquatic worms and aquatic snails).

Macrophytes - aquatic plants that grow in or near water and can be emergent, submergent or floating.

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

MDBA – Murray-Darling Basin Authority.

Overbank flow - flood flows that overtop the river bank and spill onto the floodplain.

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

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

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

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

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

Riparian vegetation - vegetation growing on the water line, up the bank or along the very top of the bank. It is the vegetation which has the most direct effect on instream biota.

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

The Living Murray (TLM) - an intergovernmental program, which holds an average of 500,000 ML of environmental water per year, for use at six icon sites along the River Murray.

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

Victorian Environmental Flow Monitoring and Assessment Program (VEFMAP) – scientific monitoring that assesses the effectiveness of environmental flows in delivering ecological outcomes.

Victorian Environmental Water Holder (VEWH) - an independent statutory body responsible for holding and managing Victorian environmental water entitlements and allocations (Victorian Environmental Water Holdings).

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

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

Waterway manager - agency responsible for the environmental management of waterways (includes Catchment Management Authorities and Melbourne Water).

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

Introduction

Purpose

This Seasonal Watering Proposal (SWP) outlines the Goulburn Broken Catchment Management Authority's (GB CMA) priorities for the use of environmental water in the lower Broken Creek and Nine Mile Creek in 2023-24, as required under section 192A of the *Water Act 1989*. It aims to:

- identify the environmental water requirements of the lower Broken and Nine Mile Creeks in the coming year under a range of climatic scenarios to protect or improve the environmental values and health of these waterways; and
- inform the development of environmental water priorities in the VEWH's Seasonal Watering Plan for 2023-24.

The SWP is informed by scientific studies and reports that identify the flow regime required to meet the ecological objectives of the creeks. It was prepared in consultation with key stakeholders and partners, and was approved by the GB CMA CEO.

System overview

The lower Broken and Nine Mile Creeks are within the Broken River Basin in northern Victoria.

The Broken Creek is a priority waterway in the Goulburn Broken Waterway Strategy 2014-2022 and the floodplain of the lower Broken and Nine Mile Creeks is listed in the 'Directory of Important Wetlands in Australia' (Environment Australia 2001). Stretches of the Broken and Nine Mile Creeks have been reserved as State Park and Natural Features Reserve. The creeks support a diverse and abundant native fish community, including threatened Murray cod (*Macullachella peelii peelii*), golden perch (*Macquaria ambigua*) and silver perch (*Bidyanus bidyanus*). Along with their floodplain and wetland habitats, the creeks are culturally significant to the Yorta Yorta Traditional Owners, provide water for agriculture and urban centres, and support a variety of recreational activities.

The lower Broken and Nine Mile Creeks form part of the Murray Valley and Shepparton Irrigation Districts, having been regulated for over 100 years. Irrigation water is supplied to the creeks from (Figure 1):

- the Murray Valley 7/3 Main Channel - offtaking from Lake Mulwala on the Murray River and outfalling into lower Broken Creek at Katamatite.
- the East Goulburn Main Channel - offtaking from the Goulburn River (Goulburn Weir at Nagambie) and outfalling into lower Broken Creek at Katandra Weir (downstream of Katamatite).
- over a dozen smaller Murray Valley and Goulburn Valley channels (and drains) spread along and outfalling into the creeks further downstream.

The most downstream section of the Broken Creek (below Nathalia) is highly regulated, with eight shallow weir pools along the 65km reach. During the irrigation season, these are managed to provide a near-constant water level to facilitate pumping by irrigation diverters and for stock and domestic (S&D) use. Due to the shallow depths and low flow velocities in the weir pools, the lower Broken Creek is prone to low dissolved oxygen levels when temperatures increase in summer, as well as large accumulations of *Azolla* (which can also contribute to low dissolved oxygen levels through blocking light available for photosynthesis by other aquatic plants and algae, and through microbial processes when decaying).

Under natural conditions the creeks would have ceased to flow for extended periods during summer and autumn. Today, the lower Broken and Nine Mile Creeks are largely perennial with significant flows maintained throughout the irrigation season (spring to autumn) to supply consumptive water. However, winter flows have been reduced due to water harvesting and are reliant on environmental water deliveries and catchment induced runoff.

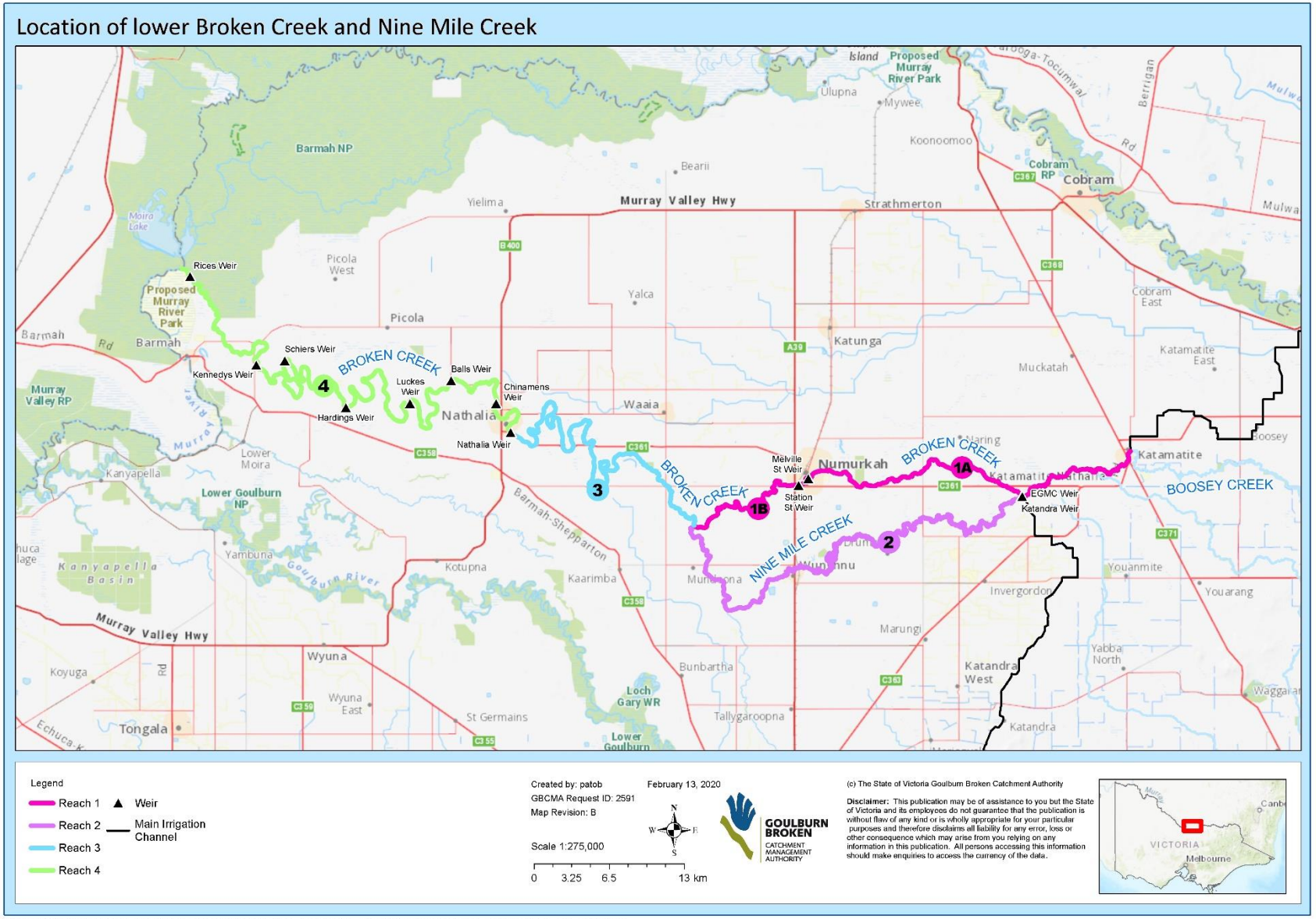

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Figure 1: Lower Broken and Nine Mile Creeks

Priority reaches and measuring points

Ecological flow recommendations were developed for the lower Broken and Nine Mile Creeks in 2018 (Jacobs 2019). The environmental flow recommendations were determined using the FLOWS methodology. The creeks were divided into four reaches with similar channel morphology, flow regimes and ecological values (Figure 1). Details of the four reaches are below:

Table 1: The four reaches in the lower Broken and Nine Mile Creek system

Reach	Description
1	Boosey Creek downstream of the Murray Valley 7/3 Channel outfall at Katamatite to Broken Creek confluence (4.1km), Broken Creek downstream of the Boosey Creek confluence to the Nine Mile Creek confluence downstream of Numurkah (38.5km). Total length – 42.6km.
2	Nine Mile Creek from Katandra Weir to the Broken Creek confluence (49.8km).
3	Broken Creek from the Nine Mile Creek confluence to the Nathalia town weir (37.9km).
4	Broken Creek downstream of the Nathalia town weir to the Murray River (65.8km).

While all reaches are important, the delivery of environmental water is targeted to reach 4 over the irrigation period, which supports the most native fish (Howson and Lloyd 2021) and often has poor water quality in summer and autumn. However, water delivered to reach 4 also provides benefits to the other reaches (upstream) during this time. Specific flow recommendations exist for the upstream reaches (1 and 2), which also provides benefits for the downstream reaches (3 and 4). The key environmental flow measurement point for reach 4 is Rices Weir. Rices Weir is the most downstream weir on the Broken Creek and is located approximately 1 km upstream of the Murray River and Broken Creek confluence (Figure 1).

Water sources

Environmental flow requirements in the lower Broken Creek system are mostly met from three main water sources – environmental water, Murray bypass flows and Goulburn to Murray Inter-Valley Transfers (IVT). Regarding environmental water, the lower Broken Creek system has no environmental entitlements or water storages. Environmental water must therefore be delivered from the Murray or Goulburn Rivers via the irrigation channel network.

Given the lower Broken Creek flows into the Murray River at Barmah Forest, water-in-transit along the Murray River can be diverted around the Barmah Choke via lower Broken Creek (referred to as Murray bypass flows). Similarly, Goulburn River flows destined for the Murray River can be diverted around the lower Goulburn River via lower Broken Creek (referred to as Inter-Valley Transfers). These water-in-transit deliveries meet a significant proportion of the lower Broken Creek system's environmental flow needs. The availability of these sources is confirmed with the Murray-Darling Basin Authority (MDBA) river operators as seasonal conditions unfold.

Water available for use in the lower Broken and Nine Mile Creeks is detailed in Table 2 and includes:

- a water quality allowance (30GL) established in the Bulk Entitlement (Eildon – Goulburn Weir) Conversion Order 1995 and subsequent amendments;
- environmental entitlements held by the VEWH, the Commonwealth Environmental Water Holder (CEWH) and the MDBA;
- Murray bypass flows;
- Goulburn to Murray Inter-Valley Transfers (IVT); and
- unregulated flows from the Murray River, Boosey Creek and upper Broken Creek.

Table 2: Bulk entitlements and water sources available for meeting environmental requirements in the lower Broken and Nine Mile Creeks

Water Source	Responsible agency	Description	Conditions
Bulk Entitlement (Eildon – Goulburn Weir) Conversion Order 1995			
Goulburn Water Quality Allowance	GMW	30 GL per year	Maintenance of water quality.
Environmental water entitlements and Water-in-Transit			
Murray River flows	MDBA /VEWH MDBA	Unregulated flows Regulated Barmah Choke bypass flows	Available when Murray River flow is unregulated. Regulated conditions when flows at or near Barmah Choke reach capacity.
Goulburn Valley and Murray Valley Irrigation supplies	GMW	Irrigation water	Supply is dictated by demand and channel capacity.
Bulk Entitlement (River Murray - Flora and Fauna) Conservation Order 1999	VEWH	29,782ML high reliability water shares and 3,894 low reliability water shares.	Availability determined by agreement with the VEWH.
NVIRP entitlement	VEWH	One-third of water savings created in the Goulburn System as a result of modernisation works completed as part of Stage 1 of the Northern Victorian Irrigation Renewal Project. Issued to the VEWH as 17,703 ML high reliability water shares.	Availability determined by agreement with the VEWH.
Environmental Entitlement – Living Murray	MDBA	39,625 ML Goulburn high reliability water shares and 156,980 ML low reliability water shares. 9,589 ML Murray high reliability water shares and 101,850 ML low reliability water shares.	Water allocated to this entitlement must be used for the Living Murray 'icon sites'. However, this water can provide environmental benefits in the lower Broken Creek system en-route to the Murray River.
Commonwealth Environmental Water Holdings	CEWO	The watering schedule between CEWO and VEWH allows up to 50,000 ML to be available for the lower Broken Creek, subject to environmental need and water availability. Additional environmental allocations may be available from CEWH holdings if required.	Approved by the CEWH and sourced from Murray and/or Goulburn holdings. Water use is subject to agreement with the representatives from the CEWO.
Goulburn River Inter-Valley Transfers	MDBA/GMW	Varies (up to 350,000 ML) depending on trade amounts.	Must be called by MDBA Limited to spare channel capacity.
Boosey Creek and upper Broken Creek flows	VEWH	Unregulated flows	Available when Boosey Creek and upper Broken Creek flow is unregulated.

Engagement

Planning

Key community and stakeholder groups have been engaged during the development of this proposal (Table 3). Similar to previous years, these groups include:

- The agencies directly involved in delivering the proposed flow recommendations including Goulburn Murray Water (GMW), the VEWH and the CEWH.
- Yorta Yorta Nation Aboriginal Corporation - the Registered Aboriginal Party under the Aboriginal Heritage Act (2006).
- Taungurung Land and Waters Council (TLaWC) – Traditional Owners to the south of the Goulburn Broken CMA region.
- Parks Victoria – the manager of the reserve system adjacent to the creek.
- Individuals or groups potentially affected by or interested in environmental flows and/or the health of the lower Broken and Nine Mile Creeks. This includes water users along the creeks (GMW diversion licence holders), campers and recreational users, local government, environment groups and the general public.

Engagement with these groups primarily occurs through two mechanisms – the Broken Environmental Water Advisory Group (EWAG) and direct engagement e.g. through meetings, email updates and one-on-one informal discussions.

The Broken EWAG was established by the GB CMA in April 2012 to provide advice on planning environmental water use (including SWPs and Environmental Water Management Plans) and on any environmental health trends occurring in the rivers, creeks and wetlands across the Broken Basin. The EWAG meets 3-4 times per year with the most recent meeting in February 2023. The focus area for the group is the Broken River from Lake Nillahcootie to Shepparton, the Broken Creek from Caseys Weir to the Murray River and wetlands associated with these systems. The group includes community members (from a range of geographic locations along the Broken River and Broken Creek), Taungurung Land and Waters Council, the Goulburn Valley Environment Group and key agency partners (the VEWH, the CEWO and GMW). Yorta Yorta Nation have also been invited to join the group. However, to date limited resources has restricted their involvement.

Direct engagement has also occurred with Traditional Owners (Yorta Yorta Nations Aboriginal Corporation and Taungurung Land and Waters Council) and program partners (GMW, the VEWH, the CEWO) through regular meetings and discussions with GB CMA staff. Examples include presentations on planned environmental water deliveries at virtual meetings with Traditional Owner groups and discussions through the Goulburn/Broken Operations Advisory Group.

Engagement during the planning process for the 2023-24 SWP indicated that community and stakeholder groups remain supportive of the proposed watering actions for the lower Broken and Nine Mile Creeks.

In addition to the above, communications about the environmental flow program and the specific environmental flows and objectives proposed in the Broken Basin for 2023-24 will occur through a variety of communication materials and products (e.g. media releases, talks and newsletter articles for special interest groups). The communications will help build the general public's awareness and understanding of environmental water in the region, particularly the resulting environmental and shared benefits. Further details are available in the Goulburn Broken Environmental Water Communication Action Plan, which is reviewed and refined throughout the year.

Operations

In relation to the delivery of the proposed flows, an Operational Advisory Group was formally established by the VEWH in early 2016 for the Goulburn and Broken systems. It is comprised of

representatives from GMW, MDBA (river operators), the VEWH, the CEWO, TLaWC and the GB CMA. It aims to provide a regular and coordinated forum to discuss and resolve aspects of environmental water management planning, delivery, approvals and facilitate system-scale coordination.

GMW is the key water delivery agency. When the final proposal for 2023-24 is agreed, communications with GMW are aimed at making clear what the intended environmental flow release plans are and their intended purpose. Then, throughout the season, there will be regular communications (phone, email) directly with the water resource management team in GMW to understand unregulated flows, GMW planned consumptive use releases, and to organise environmental flow releases.

MDBA (river operators) is responsible for requesting Inter-Valley Transfers and use of Barmah Choke bypass flows. Communications (phone, email) will be aimed at initially planning Inter-Valley Transfers and use of Barmah Choke bypass flows to achieve Murray River system operational objectives and lower Broken Creek environmental objectives, and then regularly throughout the season, adjusting the plans to conditions as they unfold.

The VEWH will use this proposal as the basis (in whole or part), in developing their Seasonal Watering Plan. Water allocated is to be delivered in accordance with the plan and the plan is used to seek agreement from other water holders for the use of their water. Routine communication (phone, email) will report on deployment of water under the plan, and seek to modify release plans to align with downstream site needs as the year unfolds.

The CEWO also undertakes annual planning and publishes plans on the CEWO website. Planning by the GB CMA, the CEWO and the VEWH is undertaken in close co-operation with each other to create a shared understanding of the watering priorities and ecological outcomes to be achieved each year. The CEWO is responsible for achieving further benefits from the water at downstream environmental sites. Routine communication will be via the VEWH.

Table 3: Engagement during development of the lower Broken Creek Seasonal Watering Proposal

Who		IAP2 level of engagement	Engagement methods	Engagement purpose
Government agencies	GMW VEWH CEWH Parks Victoria	Collaborate	Broken EWAG meeting 13 February 2023 Direct engagement	Seek input to development of the proposal. Understand any delivery constraints or issues and plan for environmental water delivery in 2023-24.
	Goulburn Valley Water	Inform	Email regarding planned watering actions 1 February 2023	Keep relevant water authorities informed about planned watering events.
Traditional Owners	Yorta Yorta Nation Aboriginal Corporation	Involve	Direct engagement – meeting on 18 January 2023	Identify Aboriginal values and uses of the creeks. Seek feedback on environmental water priorities for 2023-24.
	Taungurung Land and Waters Council	Involve	Broken EWAG meeting 13 February 2023 Direct engagement – meeting on 22 February 2023	
Recreational Users	EWAG members	Involve	Broken EWAG meeting 13 February 2023	Confirm recreational and social uses of the creeks. Seek feedback on environmental water priorities for 2023-24.
	Nathalia Angling Club and Numurkah Fishing Club	Inform	Email regarding planned watering actions 1 February 2023	Keep key interest groups informed about planned watering events.
Community and Environment Groups	Broken Creek Field Naturalists Club	Inform	Email regarding planned watering actions 1 February 2023	Keep key interest groups informed about planned watering events.
	Broken Boosey Conservation Management Network	Inform	Email regarding planned watering actions 1 February 2023	
	Goulburn Valley Environment Group	Involve	Broken EWAG meeting 13 February 2023	
	Goulburn Murray Landcare Network	Inform	Email regarding planned watering actions 1 February 2023	
Landholders	EWAG members	Involve	Broken EWAG meeting 13 February 2023	Gather observations on creek health and trends. Seek feedback on environmental water priorities for 2023-24.
Local Government	Moira Shire	Inform	Email regarding planned watering actions 1 February 2023	Keep local shire informed about planned watering events.

Aboriginal cultural values and uses of waterways

Traditional Owners value water in the landscape's waterways and wetlands as a way of caring for country, for supporting culturally important plants and providing opportunities to practice culture. Yorta Yorta Nation Aboriginal Corporation is the Registered Aboriginal Party for the lower Broken Creek system, under the Aboriginal Heritage Act (2006).

During consultation with Yorta Yorta in previous years, the following cultural values have been identified for the lower Broken Creek:

"The Broken Creek holds many cultural values. Common reed contained within the slack water provides important material for tools whilst also providing refuge for culturally important fish species (large & small bodied). The creek also has significant stands of old growth river red gum containing important habitat and exhibiting scars made from carving out canoes and coolamons" (J. Whittaker, pers. comm. 4 March 2021).

The Yorta Yorta Whole of Country Plan 2021-2030 includes Broken Creek as a priority place with high value including native fish populations, turtles, platypus, rakali, Australiasian bittern and threatened River swamp wallaby grass. Threats around inadequate flow leading to low oxygen levels and overabundant *Azolla* are identified. The Plan outlines Walla (water) actions to "achieve healthier Country and better outcomes for ecosystems and native plants and animals" including improving "volumes, seasonality, timing and depth of river flows" and "the cultural and environmental outcomes from watering operations". This includes protecting "culturally important animal species, especially turtles, through measures to conserve land and water habitat".

The environmental objectives of this SWP were supported by Yorta Yorta and align with their values of caring for Country. Flows have been specifically targeted to support instream vegetation and native fish, along with other aquatic biota. The GB CMA will continue to work with Yorta Yorta Nation to identify how environmental water management can best support cultural values.

In previous meetings to discuss SWPs, Yorta Yorta raised concern about the cultural damage water transfers are having on the lower Goulburn River and the Barmah Choke, this was in addition to the ecological damage being caused. Using the lower Broken and Nine Mile Creeks for delivery of water (either environmental or consumptive) to the lower Murray River as a bypass mechanism, may help reduce risk of erosion on the Barmah Choke and lower Goulburn River and thus help to protect culturally significant values. Use of lower Broken Creek as an alternative pathway for such deliveries has been identified in the Yorta Yorta Whole-of-Country Plan (2021-2030).

Social, recreational and economic values and uses of waterways

The creeks making up the lower Broken Creek system have a narrow riparian zone with residential and farming properties adjoining or overlooking them. The creek system runs through the Katamatite, Wunghnu, Numurkah and Nathalia townships. Consequently, the communities have a direct connection with their creek, which provides high aesthetic and amenity value, that is particularly important to the mental health and wellbeing of the community. The creeks are also important recreational areas in terms of fishing, canoeing, kayaking and passive recreation.

"The Broken and Nine Mile Creeks are important in regards to being one of the most accessible waterways in Victoria for fishing, family picnics and camping" (Nathalia community member, 22 February 2023).

Delivery of water for the environment has helped support these activities e.g. through providing baseflows that keep fishways operational and ensure over-wintering habitat is provided for young-of-year fish, as well as freshes that provide movement and spawning cues for key species such as Murray cod. Winter flows maintain adequate depth for recreational pursuits such as canoeing. Water for the environment is also critical for maintaining good water quality in the creek,

particularly following natural flood events that can be associated with hypoxic blackwater and strong odour.

The lower Broken Creek system is the source of consumptive water (irrigation and S&D) for over 70 diverters. Lower sections of the creek are prone to poor water quality (high turbidity, low dissolved oxygen levels and elevated concentrations of nutrients and suspended solids) (Sinclair Knight Merz 1996; Cottingham et al. 2011; GHD 2005). Delivery of baseflows and freshes during the warmer months has contributed to improved water quality for local diverters.

The expected shared benefits from delivery of water for the environment in the lower Broken Creek and Nine Mile Creek in 2023-24 are outlined below. These are based on the shared benefits that were realised in previous years and the outcomes of community and stakeholder engagement.

Table 4: Social, recreational and economic shared benefits from environmental water in the lower Broken and Nine Mile Creeks

Shared benefit	Beneficiary	How flows contribute to the shared benefit
Amenity	General community, adjacent landholders, visitors	Baseflows retain (aesthetically pleasing) flowing habitat (almost) year-round. Higher flow in warmer months prevent water quality problems (e.g. algal blooms, large *Azolla* accumulations) and promote visual waterway productivity and biodiversity e.g. vegetation growth on the banks, waterbirds, flowering aquatic plants. Dilution flows during blackwater events help manage visual and olfactory impacts, particularly in townships and popular reserve areas.
Recreation	Local residents, visitors, anglers, game hunters, kayakers and canoers.	Baseflows retain flowing habitat year-round, keep fishways operational and provide over-wintering habitat for young-of-year fish (when delivered). This ensures water of adequate depth is available (almost) year-round for recreational activities. It also promotes the survival and recruitment of young native fish into the fish community, which supports a sustainable fishing industry. Higher flows prevent water quality problems (e.g. algal blooms, large *Azolla* accumulations) improving access to good quality water for recreational pursuits. High flows also promote waterway productivity and optimal conditions for fish (food and habitat provision), which again supports a productive and sustainable fishing industry.
Economic	Consumptive water users – GMW irrigators and diverters, Goulburn Valley Water (GVW) customers.	When delivered, winter baseflows retain flowing habitat (reducing weir pool stagnation in winter) and maintain suitable water levels for S&D pumping out of the irrigation season. Higher flows help improve water quality for all users by: • breaking up and flushing *Azolla* accumulations, reducing the potential for low dissolved oxygen associated with decaying *Azolla* and keeping the main channel clear to improve pumping access. • reducing stagnation in weir pools and the likelihood of low dissolved oxygen levels over the warmer months. • diluting point source concentrations of nutrients and other potential pollutants from drainage outfalls. Dilution flows during blackwater events help maintain water quality so that water treatment by GVW can continue and consumptive water doesn't need to be trucked into towns such as Nathalia (as happened during the spring 2022 flood event at great expense).

In recent years, members of the Numurkah community have raised concerns about the visual and ecological impact of the lower Broken Creek being drained over winter (including submitting a letter to the editor at the Numurkah Leader, June 2020). They have requested winter baseflows be provided to maintain the creek habitat, particularly around the Numurkah township. This supports

the amenity and recreational value of the creek to the local community. In the last five years, delivery of the winter baseflow has not been possible over the entirety of the irrigation off-season due to GMW maintenance works.

Seasonal review

Historic flow conditions

Prior to 2001, flows in the lower Broken Creek at Rices Weir were relatively high and variable, typically averaging 200 ML/d or more. Flows reduced significantly during the Millennium Drought (2001-2009), especially in 2002/03 and 2006/07. Flows ceased through Rices Weir for most of winter/spring 2002/03, with a major fish death occurring in November 2002, in response to low flows and the decay of large *Azolla* accumulations. Flow events greater than 500 ML/day (generated by catchment runoff) only occurred for short durations in 2003/04 (3 events), 2004/05 (1), and 2005/06 (1). No bank-full events (~2,600 ML/day) eventuated.

In 2010/11, three natural flood events occurred, with flows up to 2,140 ML/day in September, 3,570 ML/day in December, and 1,880 ML/day in February. A blackwater event accompanied the December flood with associated fish deaths. Further flooding eventuated in March 2012 (a major flood event greater than a 1 in 100 year event), with bank-full flows continuing into April. This was again accompanied by a blackwater event with low dissolved oxygen and some fish deaths.

From 2012 to 2016 flow conditions reflected the typical 'flow-inverted' stream pattern, with generally low flows over winter, higher flows during the summer irrigation season and low levels of dissolved oxygen in summer in response to high ambient temperatures. On occasion, local rainfall and catchment runoff resulted in winter freshes e.g. July 2013.

In 2016, two natural flood events occurred, with flows up to 2,200 ML/day at Rices Weir in late August and flooding from September to November resulting in a peak of around 3,000 ML/day (at Harding's Weir). During the second unregulated flow event, the Murray River saw major flooding with a peak discharge of over 196,000ML/day below Yarrawonga Weir. On 7 October, the Murray River backed up over Rices Weir and the lower parts of Broken Creek were essentially part of the Murray until 6 November.

Drier conditions prevailed from 2017 to 2022, with the exception of short periods of higher natural inflows (e.g. approximately 700 ML/d in December 2017 and 500 ML/d in late winter/spring 2021). Very wet conditions during 2022 resulted in two natural flood events in October/November, with flow peaking at 4,855 ML/d at Rices Weir. Murray River backwater again overtopped Rices Weir from September 2022 to mid-January 2023. Hypoxic blackwater associated with the flooding resulted in a large fish death event.

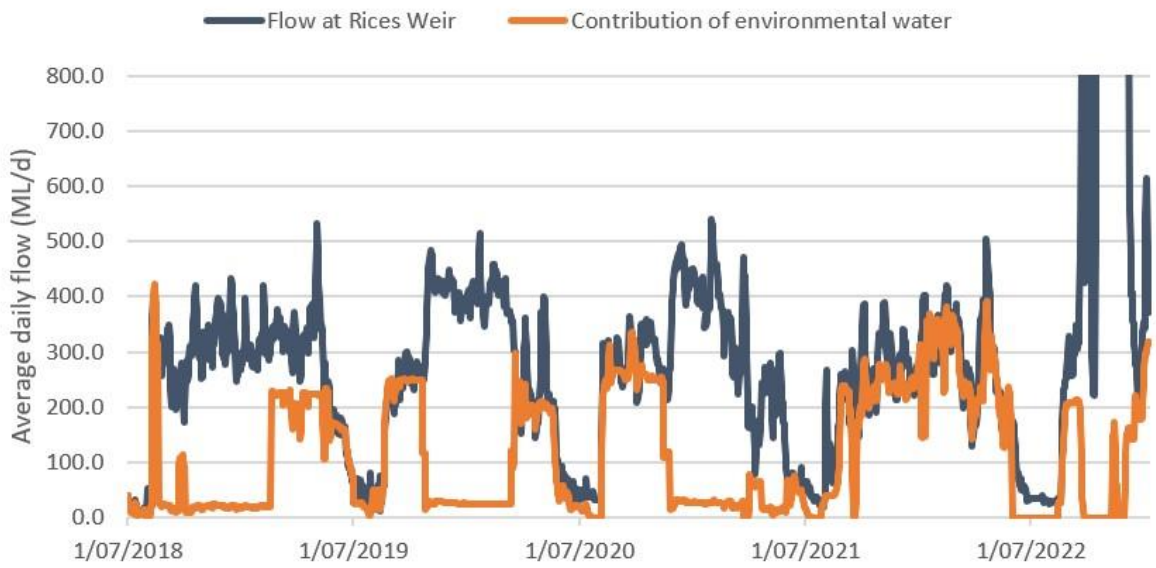


Figure 2: Total flow and the contribution of environmental water in the lower Broken Creek (2018 to January 2023)

Historic flow components delivered

Prior to 2010/11, there was no environmental water available for the lower Broken or Nine Mile Creeks. Flow management was instead provided by redirecting (via lower Broken Creek) Goulburn River and Murray River water passing to the Murray River downstream, and by deployment of the Goulburn River Water Quality Reserve.

In 2010/11, environmental water was used for the first time in the lower Broken Creek system between November and May. Environmental water has since continued to be delivered each year in the lower Broken and Nine Mile Creeks, in line with flow recommendations.

The key flow components for the lower Broken and Nine Mile Creeks include:

- winter low flow
- spring/summer/autumn low flow
- winter/spring freshes.

The achievement of these flow components in reach 4 of the lower Broken Creek[1] since 2013/14, as a result of delivering environmental water, unregulated and regulated flows is shown below (Table 5). In summary, since 2013/14:

- Winter low flow (40 ML/d to provide fish passage through the fish ladders[2] and other environmental benefits) has been completely or partially met over the past decade, with the exception of last year due to an extended duration of GMW maintenance works. The delivery of environmental water in conjunction with unregulated flows has been critical to the provision of this flow component during the irrigation off-season (15 May to 15 August). Typically, flows during the winter period hover around the minimum flow target but may not consistently achieve it. In most years, necessary infrastructure maintenance by GMW mean minimum low flow targets cannot be achieved for a period of time during the irrigation off-season.
- Spring/summer/autumn low flow (typically 250-350 ML/d, but ranging from 200-450 ML/d, to mobilise *Azolla*, maintain water quality, improve instream habitat and attract

[1] Based on the Rices Weir compliance point. Achievement of flow targets in the other reaches is described ahead.

[2] Operational since 2002.

fish) has been partially or completely met over the past decade. Generally targeted flows occur frequently, but not necessarily consistently over time. They are typically achieved through environmental water deliveries complementing consumptive deliveries and unregulated flows. In recent years, Inter-Valley Transfers (IVT) from the Goulburn River and Murray Bypass flows through the lower Broken and Nine Mile Creeks have contributed significantly to the provision of spring/summer/autumn low flow.

- Freshes (of 300-450 ML/d to cue fish movement/spawning and mobilise *Azolla*) have been met in most years and partially achieved in others. In winter/spring of 2021, a fresh delivery using environmental water was not required due to low *Azolla* levels. Environmental water deliveries have contributed significantly to the provision of historic spring freshes. In some years, freshes occur, but later than that recommended in flow studies due to the timing of operational deliveries.

Historic annual environmental water deliveries to the lower Broken and Nine Mile Creeks to achieve these flow components have ranged from 30,000 ML to 70,000 ML.

Table 5: Hydrological achievement over time

Flow component	Hydrological achievement of flow components over time									
	2013-14	2014-15	2015-16	2016-17	2017-18	2018-19	2019-20	2020-21	2021-22	2022-23*
Winter low flow (40ML/d)	U	E/O/U	E/U	U	E/U	E/U	E/U	E/U	E/U	
Spring/summer/autumn low flow (200-450 ML/d)	E/O/U	E/O	E/O/U	E/O/U	E/O/U	E/O/U	E/O/U	E/O/U	E/U	U
Winter/spring freshes (1 to 3 events of 300-450 ML/d for 1-2 weeks, Jul-Sep)	E/O/U	E/O	E/O/U	U	E/U	E/U	E/O/U	E/O/U	Not required or achieved through any deliveries	U

* Described further below

Key:

	No significant part of the flow component achieved
	Flow component partially achieved
	Flow component has been completely achieved, i.e. complete duration, frequency and magnitude was achieved

E	Managed environmental water release
O	Consumptive water en route/other managed flow
U	Unregulated flows
X	Unknown

End of previous season (2021-22) flow conditions and components delivered

Delivery of water for the environment was critical for maintaining flow and habitat in lower Broken Creek at the end of last season, in the absence of water-in-transit deliveries (i.e. IVT and Murray bypass) (Figure 3). Typical peak irrigation demand in autumn meant flow targets at Rices Weir could not be achieved in late March and early April. However, rainfall in April and a subsequent drop in irrigation demand provided an opportunity to trial delivery of an autumn fish attractant flow as part of a multi-site event in the mid Murray system. The attractant flow peaked around 500 ML/d, providing optimum conditions to test the effectiveness of this type of delivery for attracting fish such as silver perch and golden perch from the Murray River into lower Broken Creek. A total of 70 silver perch were tagged by ARI at Torrumbarry in early March, with acoustic receivers placed at the entrance to several Victorian tributaries (including upstream and downstream of lower Broken Creek) to track movement of these fish into Victorian waterways. Results are pending.

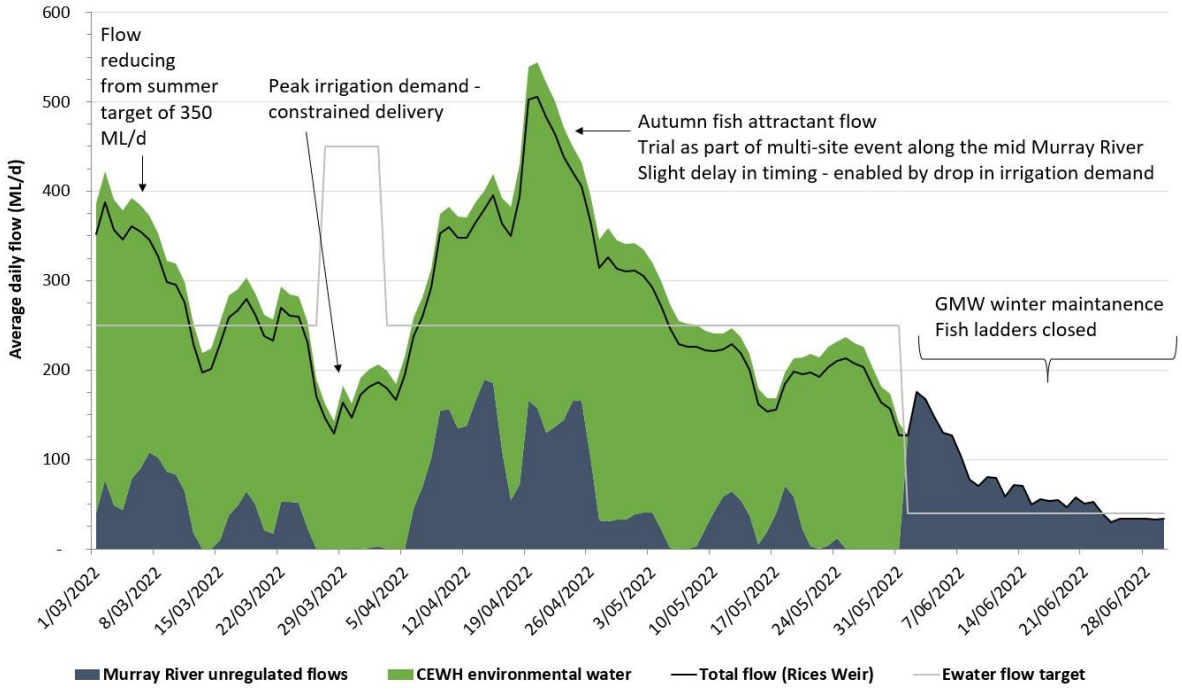


Figure 3: Flow at Rices Weir compared to target flow at the end of last season

Flow in lower Broken Creek gradually reduced from 311 ML/d to 156 ML/d at Rices Weir over May as the channel network commenced dewatering in preparation for GMW's weed control works across the Murray Valley and Shepparton irrigation districts. This meant flow was less than the 250 ML/d target most of the time. No environmental water was delivered for the remainder of the 2022/23 season while the weed control was undertaken. Some unregulated inflows continued to enter the creek from Boosey Creek and upper Broken Creek (Figure 4), however instream habitat was limited, particularly outside weir pools. Regulating gates and fish ladders along the creek were closed to maintain as much weir pool refuge habitat as possible. Azolla monitoring in June revealed acceptable levels and no accumulations that required specific flow management later in winter.

In terms of complementary works, freshwater catfish (*Tandanus tandanus*) were translocated to lower Broken Creek on 19 May as part of a plan to re-establish a self-sustaining population. The work (funded through the MDBA's Tri-State Alliance) was a collaboration between Goulburn Broken CMA, the Arthur Rylah Institute, Victorian Fisheries Authority, Lower Murray Water, OzFish

Unlimited and North Central CMA. Each fish was measured and weighed. Larger fish were also tagged to track their movement (Figure 5).

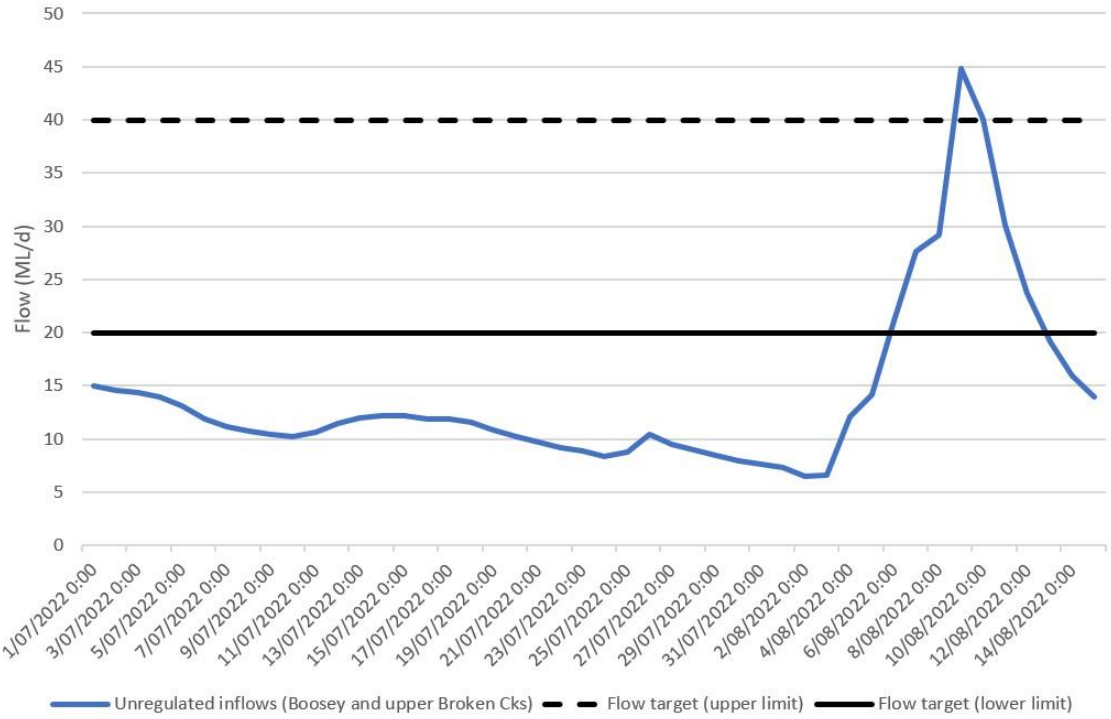


Figure 4: Unregulated inflows from Boosey and upper Broken Creeks at the end of last season

Photos: Simon Casanelia

Figure 5: Freshwater catfish released into lower Broken Creek by ARI

Current season (2022-23) flow conditions

The ongoing La Niña resulted in very wet conditions across Victoria particularly in late winter and spring (BOM 2023) (Figure 6). The Goulburn Murray Irrigation District (GMID) commenced the season with the highest opening allocations in 20 years (66% and 94% for the Goulburn and Murray, respectively). Good winter rainfall in August and corresponding storage inflows resulted in 100% High Reliability Water Shares (HRWS) being available at the start of September (the first time this had happened since 1997/98). Ongoing wet spring conditions and high storage inflows meant all major storages were at capacity by mid-September and were managed for airspace into December 2022. Releases from Lake Eildon peaked at 36,100 ML/d in October 2022, while Hume releases peaked at 91,700 ML/d in November, both resulting in downstream flooding.

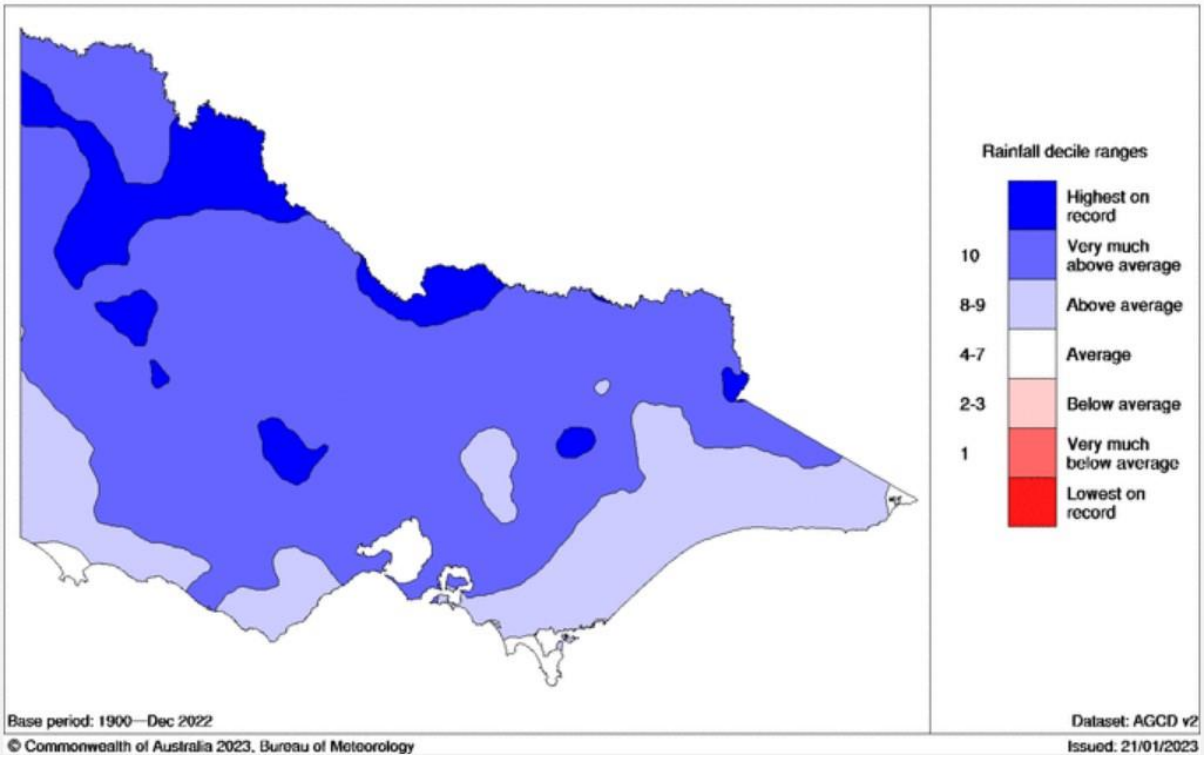
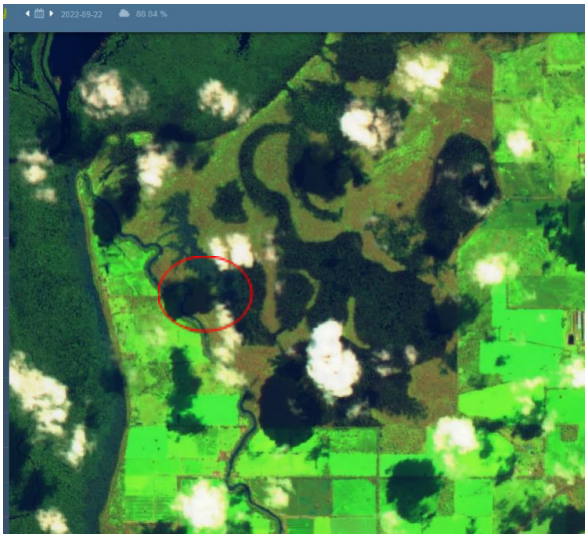


Figure 6: Victorian rainfall deciles 1 July-31 December 2022

While water allocations were high, very little water for the environment was delivered in the winter/spring of 2022. Water for the environment could not be provided to lower Broken Creek over July 2022 due to GMW maintenance works. Outside of weir pools, instream habitat remained limited. With the commencement of the irrigation season, outfall deliveries gradually increased over August, with the 250 ML/d flow target achieved towards the end of the month. Two small unregulated freshes (less than 100 ML/d) entered lower Broken Creek from Boosey Creek in August in response to winter rainfall. These pulses were delivered along Nine Mile Creek on top of environmental water deliveries from East Goulburn Main, to promote natural flow variability through the creek.

High flow in the Murray River (60,000 ML/d at Yarrawonga) resulted in water backing up into lower Broken Creek at the start of September. This drowned out Rices Weir impacting on flow gauge readings (Figure 7). Wet conditions also facilitated two natural freshes in the Boosey Creek, with the largest of these (1,400 ML/d) resulting in localised flooding of some low-lying wetland areas along the upper reaches of the lower Broken Creek system. In conjunction with the high backwater at Rices Weir pool, this natural fresh assisted with inundation of Goose Swamp in Barmah Forest (see satellite imagery below).

Above: Murray River backwater at Rices Weir, 2 September 2022 (photo: Daniel Lovell)



Above: Inundation of Goose Swamp in Barmah Forest – water breaking out of lower Broken Creek circled red

Figure 7: Murray River backwater overtopping Rices Weir and inundating Goose Swamp

The continuation of high rainfall in October resulted in very large unregulated inflows to lower Broken Creek from both the Boosey Creek and upper Broken Creek systems. Inflows at the upstream end peaked at 6,672 ML/d in mid October and gradually moved through the system by the end of the month (Figure 8). Ongoing high flows in the Murray River meant Rices Weir remained submerged. Flow at Hardings Weir showed some attenuation of the flow peak (5,400 ML/d) as water spilled onto the floodplain. Moderate flood levels were reached at Walshes Bridge and Nathalia. The high natural flows entering the creek brought with it a significant amount of organic material which lead to widespread and extended hypoxic water quality in the creek. Dissolved oxygen levels reduced to 0mg/L for approximately 1 week (Figure 9). The absence of adequate oxygen in the water column led to the death of multiple native fish including golden perch and Murray cod, as well as numerous European carp. Environmental water was unable to be used to provide freshening flows due to the continuation of very high natural flows in the creek and the risk of exacerbating flooding.

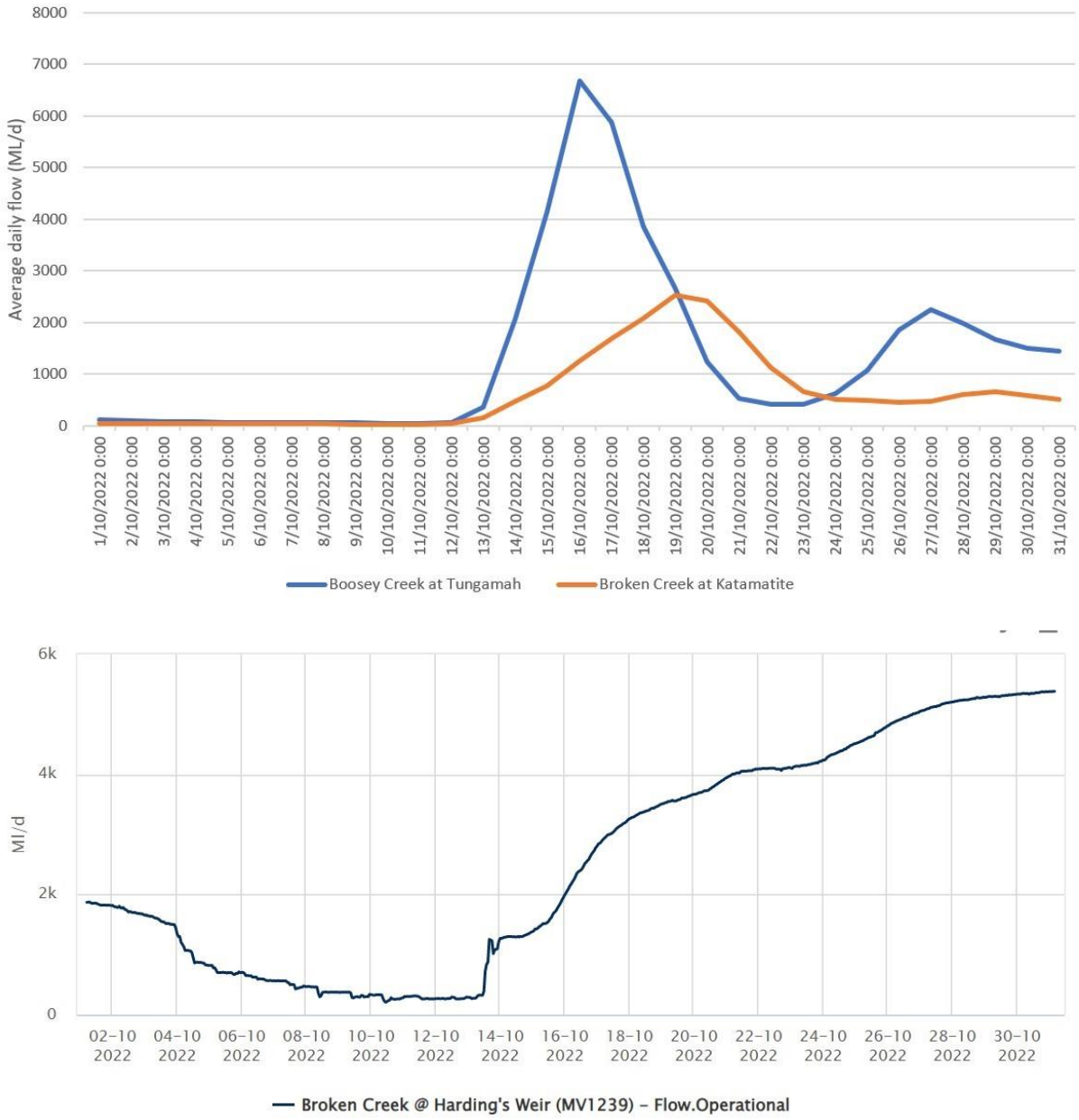


Figure 8: High unregulated inflows along lower Broken Creek in October 2022

Top graph: inflows entering reach 1 and 2. Bottom graph: inflows moving through reach 4.

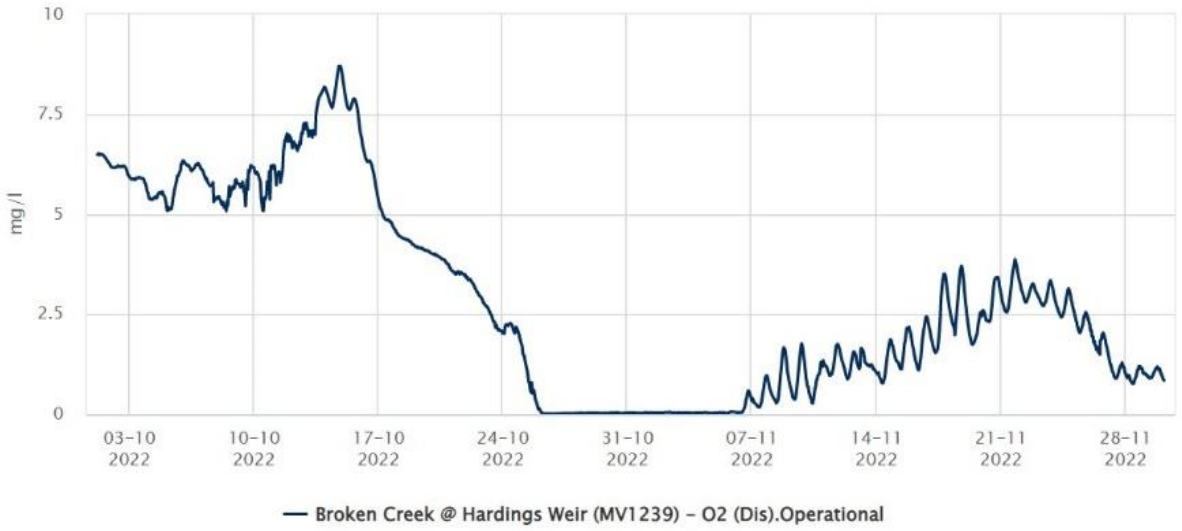


Figure 9: Extended hypoxic conditions (0mg/L) in lower Broken Creek from natural flooding

Lower Broken Creek at Walshes Bridge with flooding (left, 2/11/2022) and without flooding (right, 27/1/2023)

Above: blackwater moving through Nathalia township (2/11/2022)

Above: Luckes Weir overtopped and floodwater entering the floodplain (2/11/2022)

Above: dilution flows provided from East Goulburn Main

Above: ARI conducting fish salvage from Hicks Outfall refuge habitat prior to the November flood event (Photo: Corey Wilson)

Figure 10: Flood related images along lower Broken Creek

High rainfall resulted in another large natural fresh entering lower Broken Creek from Boosey Creek and upper Broken Creek in mid-November (~5,500 ML/d). Minor flood levels were reached at Walshes Bridge and Nathalia, and weir structures downstream of Nathalia remained overtopped. Low dissolved oxygen levels persisted across the system from ongoing blackwater inflows and increasing water temperatures (Figure 9). Outfall deliveries to supply water quality refuge habitat were provided from 10-20 November (in between high flows) using Goulburn Water Quality Reserve (160 ML/d across three sites). Local anglers reported native fish (Murray cod and golden perch) congregating at the outfalls. Prior to the outfalls being closed as the November flood approached, a fish salvage crew from the Arthur Rylah Institute electrofished two of the refuge sites with a dozen native fish captured and translocated to the Broken River, where water quality was stable. This included threatened Murray cod, golden perch and Murray-Darling Rainbowfish (Figure 10).

Stable conditions returned over summer with unregulated inflows reducing to small volumes (<10 ML/d) and environmental water deliveries targeting 350 ML/d at Rices Weir to maintain dissolved oxygen levels during periods of high summer temperatures. Dissolved oxygen levels remained satisfactory over December/January despite water temperature increases to around 30 deg C. In late January, a blue green algae warning was issued for the Murray Valley irrigation area. GMW turned off the majority of Murray Valley outfalls (by 110 ML/d) to limit the spread of blue green algae in lower Broken Creek (although 20 ML/d continued to be supplied from the 7/3 channel to retain flow

in reach 1b). Median flow at Rices Weir was 260 ML/d during this time, with Murray Valley outfalls turned back on (and targeting 350 ML/d at Rices Weir) in mid-February when the risk of blue green algae subsided.

Current season (2022-23) flow components delivered

Based on the 2016 FLOWS study, specific flow components have been recommended for each reach of the lower Broken Creek system. An audit against the delivery of the planned flow components in 2022-23 has been conducted for each reach, as shown in the below tables and figures.

The assessment highlights the following:

- Winter low flow targets were only partially or not achieved for the fifth year in a row due to maintenance works. Opportunities to coordinate GMW maintenance works between the Shepparton and Murray Valleys will continue to be explored.
- A managed spring fresh delivery was not required due to ongoing low *Azolla* levels. However, multiple spring freshes were provided through natural inflows and flooding.
- Summer low flows were variable, with the 350 ML/d flow target partially achieved. The closure of most Murray Valley outfalls in late January (to reduce blue green algae entering the creek) prevented the 350 ML/d target being achieved in the first half of February.

Note: some flow components may be better described as operational recommendations e.g. management of weir pool levels and flow diversion splits downstream of weirs. However, these have been included with the other flow components for completeness of the assessment.

Table 6: Audit of flow component delivery in reach 1 of lower Broken Creek (2022-23)

Section of reach	Flow component	Achieved in 2022-23	Explanation
1a – Broken Ck upstream of Katandra Weir pool	Full Supply Level in Katandra Weir (Dec-Mar) for platypus. Drawdown does not exceed 30cm in irrigation off-season.	Partial achievement	Weir pool drawdown was substantial (>30cm) over winter (due to GMW maintenance works) and intermittently during spring to help manage flooding inflows. Field observations in January revealed Katandra Weir pool was at Full Supply Level and is expected to have remained stable during summer (in the absence of high unregulated inflows).
1b – Broken Ck downstream of Katandra Weir to Nine Mile Ck confluence	Winter low flow (20-40 ML/d)	Partial achievement	Unregulated inflows from the Boosey and upper Broken Creeks during July/August, in the absence of environmental water, provided some baseflow (predominantly around 10 ML/d, with a two week period above 20 ML/d).
	Fresh (100-200 ML/d, for 1-2 weeks at least to connect, August-November. But noting 120 ML/d capacity constraint in this reach).*	Achieved	A managed fresh was not required due to very low *Azolla* levels. However, a natural fresh occurred in September that met this flow component.
	Avoid constant high flows, especially in summer and autumn	Achieved (to date)	Flow at Numurkah (reach 1) post flood showed an absence of constant high flow over summer (~30-240 ML/d).
	Split flow between reach 1 and 2 unless flows are too low (<10ML/d), in which case prioritise flows to lower Broken Creek due to higher habitat and submerged vegetation values being present in this reach.	Achieved	Flow split was maintained as natural inflows remained around 10 ML/d or above.

* The FLOWS study recommends 1-3 fresh events per year including an initial fresh to occur in July to help mobilise *Azolla* in downstream reaches (if necessary) and a follow-up fresh in August/September to inundate littoral vegetation. This has been extended into November to account for water temperatures required to prompt native fish migration. Monitoring in July detected low *Azolla* levels across reach 4 and a fresh for *Azolla* management was therefore not required. *Azolla* monitoring results are discussed further ahead.

Table 7: Audit of flow component delivery in reach 2 – Nine Mile Creek (2022-23)

Flow component	Achieved in 2022-23	Explanation
Winter low flow (20-40 ML/d)	Partial achievement	Unregulated inflows from the Boosey and upper Broken Creeks during July/August, in the absence of environmental water, provided some baseflow (predominantly around 10 ML/d, with a two week period above 20 ML/d).
Fresh (100-200 ML/d, for 1-2 weeks at least to connect, August-November).*	Achieved	A managed fresh was not required due to very low *Azolla* levels. However, a natural fresh occurred in September that met this flow component.
Avoid constant high flows, especially in summer and autumn	Achieved (to date)	Flows have been variable due to unregulated inflows and an absence of high IVT/Murray bypass demand.

* The FLOWS study recommends 1-3 fresh events per year including an initial fresh to occur in July to help mobilise *Azolla* in downstream reaches (if necessary) and a follow-up fresh in August/September to inundate littoral vegetation. This has been extended into November to account for water temperatures required to prompt native fish migration. Monitoring in July detected low *Azolla* levels across reach 4 and a fresh for *Azolla* management was therefore not required. *Azolla* monitoring results are discussed further ahead.

Table 8: Audit of flow component delivery in reach 3 and 4 of lower Broken Creek (2022-23)

Flow component	Achieved in 2022-23	Explanation
Winter low flow (40 ML/d)	Not achieved	Winter low flow could not be delivered due to GMW maintenance works. Flow at Rices Weir in July and August was a combination of unregulated inflows and channel dewatering. Consequently, the flow target at Rices Weir was not achieved. Flow ranged from 28-36 ML/d over this period.
Fresh (300-450 ML/d, for 1-2 weeks, August-November).*	Achieved	A managed fresh was not required due to very low *Azolla* levels. However, multiple natural freshes occurred in spring and met this flow component.
Spring/summer/autumn low flow (200-450 ML/d, July to May).	Partial achievement	Spring flow was very high due to flooding, with flood waters still receding in early December. Post flooding, the summer low flow target to manage dissolved oxygen levels (350 ML/d) was partly achieved. Flow varied greatly over summer and the closure of Murray Valley outfalls to manage the spread of blue green algae prevented the flow target being achieved in the first half of February 2023.
Avoid constant high flows, especially in summer and autumn	Achieved (to date)	Flow at Rices Weir has varied considerably in response to unregulated inflows.

* The FLOWS study recommends 1-3 fresh events per year including an initial fresh to occur in July to flush *Azolla* (if necessary) and a follow-up fresh in August/September to trigger fish movement. This has been extended into November to account for water temperatures required to prompt native fish migration. Monitoring in July detected low *Azolla* levels across reach 4 and a fresh for *Azolla* management was therefore not required. *Azolla* monitoring results are discussed further ahead.

The contribution of different water sources to the flow in lower Broken Creek at Rices Weir over 2022-23, compared to the flow target, is shown in Figure 11.

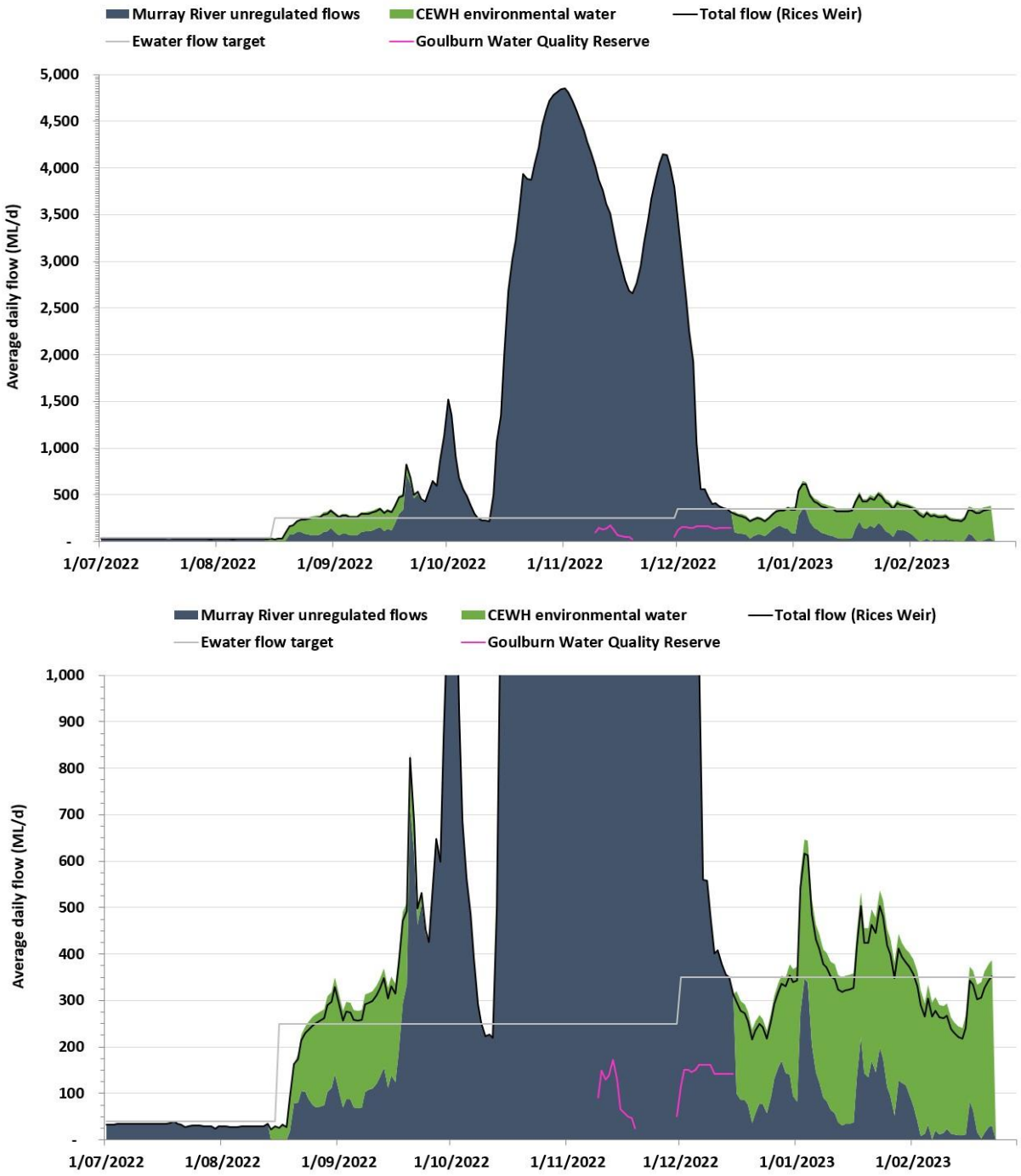


Figure 11: Comparison of planned flow against actual flow at Rices Weir (reach 4)

Environmental outcomes 2022-23

Delivery of environmental water to the lower Broken and Nine Mile Creeks in 2022-23, in conjunction with unregulated inflows, resulted in the following environmental outcomes (Table 9). These have been identified based on field observations in conjunction with scientific, flow and water quality monitoring at several locations.

Table 9: Environmental outcomes from environmental water delivery along the lower Broken and Nine Mile Creeks 2022-23

Ecological value	Environmental outcomes achieved in 2022-23
Native fish and other native aquatic animals	Closing the fish ladders during the GMW maintenance period (when winter low flow could not be provided) retained as much water and habitat as possible within the weir pools for native fish, platypus, Rakali and turtles. This was very important for survival of aquatic fauna, as elsewhere in the system instream habitat was severely compromised. Outside the maintenance period, fish ladders remained open and provided longitudinal connectivity through the system. Delivery of environmental water prior to the spring flooding, maximised the instream habitat available coming into the breeding season as water temperatures increased. Unfortunately, the high natural flows in October/November had a detrimental impact on the native fish community with hypoxic conditions causing many fish deaths and also impacting on available food supplies for native fish. Reports from several local anglers indicated key macroinvertebrates such as shrimp and yabbies were absent from large areas of the creek for many weeks. *"Shrimp still impossible to catch in the Broken Creek at the moment, although the yabbies have returned in good numbers"*, local angler Facebook comment 18 January 2023. Small volumes of Goulburn Water Quality Reserve were delivered from several Shepparton Irrigation District outfalls between the two large spring flood events. These provided critical water quality refuge habitat, with multiple locals and CMA staff reporting native fish accumulating at these locations. Fish salvage efforts at two outfalls prior to the arrival of the second flood peak captured Murray cod, golden perch and Murray darling rainbowfish. While disappointing, the fish death event showed a good age class distribution of both Murray cod and golden perch were present in the creek. A fish survey in autumn 2022 found good recruiting conditions had been present in the creek, with relative high numbers of young-of-year Murray cod compared to historic data and newly recruited Murray darling rainbowfish (Gower et al. 2022). Golden perch numbers have also been increasing over time (GBCMA 2022). An autumn fish survey is planned for 2023. This is expected to detect a large increase in the biomass of European carp, which have been observed in very high numbers on the creek since the flooding. The return of water for the environment since the spring floods has assisted in the recovery of water quality along the creek, with suitable dissolved oxygen levels maintained despite increasing summer water temperatures (to around 30 deg C).
Native vegetation	Provision of spring/summer low flows maintained low *Azolla* levels. *Azolla* levels have remained very low across the system since the start of August 2020. The water depth covering instream macrophytes improved from that observed in winter, in line with recommendations from the FLOWS study (>50cm depth). The natural floods inundated areas of riparian floodplain vegetation for the first time since 2016. This included lignum and river red gums. Bank vegetation surveys are planned for autumn/winter 2023 and will detect changes from the 2022 survey (pre-flood).
Water quality	Described above in relation to fish habitat.

Ecological condition

The most recent monitoring on lower Broken Creek occurred in autumn/winter 2022 (before the spring floods) through DEECA's Trade Rule Monitoring Program, and included bank condition assessments, vegetation surveys and fish surveys. Continual water quality and flow monitoring along various parts of the creek inform operational management and provide information on environmental water delivery and effects on water quality. The ecological condition of the system is summarised below. This is based on the latest (pre-flood) monitoring information, as well as any field observations made during and post the spring flood event.

Table 10: Current ecological condition and trajectory for the lower Broken and Nine Mile Creeks

Ecological value	Condition summary	Expected trajectory
Geomorphology	Highly modified following European settlement through the construction of weirs, floodplain levees, dredging/re-alignments of channels and removal of in-stream habitat including snags (Jacobs 2019). Flow regulation and weirs have contributed to bank erosion, channel widening and shallowing over many decades. The poor condition of the creek banks (i.e. deep notches with overhanging ledges) suggests erosion from historic creek operations is yet to be fully realised. Recent bank condition assessments show variable erosion and deposition rates occurred from winter 2021 to winter 2022. Some sites showed minor change while other sites showed more widespread and/or greater magnitude erosion, although high-magnitude erosion (>10cm) was uncommon (Gower et al. 2022). Vegetation clearing, the supply of irrigation water combined with irrigated drainage runoff is likely to have increased the supply of fine sediments to the creeks (Jacobs 2019). Large accumulations of silt are evident throughout the system. Geomorphological changes from the spring floods will be assessed in winter 2023 when water level reduce. Several large trees fell into the creek in response to the flooding but it is currently unclear how the creek's physical form may have changed.	Declining. Flood impacts to be determined in winter surveys.
Vegetation	The 2004 Index of Stream Condition (ISC) assessed the riparian condition as average to good, with a mature overstorey (often regrowth) but degraded understorey (reduced structural complexity, reduced species richness, little or no recruitment and an understorey of non-native species). The degraded understorey is attributed to past and present stock grazing pressures and timber removal for firewood (Jacobs 2019). The littoral zone is restricted to a narrow band of perennial tufted graminoids (e.g. grasses, rushes and sedges) that reflect the constant water level during the irrigation season. Instream vegetation reflects the regulated flow regime – robust perennial species adapted to permanent or near permanent inundation and low flow velocity e.g. *Typha* and *Vallisneria*. Carp are expected to have also degraded instream vegetation. Vegetation surveys in autumn 2022 found most sites had a high abundance of flood tolerant vegetation, but abundance was lowest in places with geomorphologically unsuitable habitat, including locations with steep banks, which often coincided with outside bends of channels. Aquatic vegetation was patchy on the channel bed and emergent vegetation cover was low. Comparisons with historical data suggest that the populations of native vegetation are increasing relative to exotics, and the area of bare ground has declined with the removal of livestock grazing from many frontages. Increased water depth since the Millennium Drought has resulted in declines in flood tolerant and/or emergent vegetation populations at some sites. Tree recruitment events have occurred since the drought, resulting in patches of dense samplings on the creek margins (Gower et al. 2022). Field observations after the flood (end of January 2023) found an increase in bare ground on the banks where	Assessed as stable overall. Flood impacts to be determined in autumn surveys.

Ecological value	Condition summary	Expected trajectory
	terrestrial grasses had died from inundation. Germination of bank vegetation near the water's edge post flood included occasional patches of sparse to moderate germination of predominantly old man weed (*Centipeda cunninghamii*) and one species of sedge. Most new plant growth was on the floodplain away from the top of the bank (by at least 1m) and was dominated by sedges. The high flows had substantially reduced the presence of water primrose (*Ludwigea peploides*) in reach 4, although this is expected to return over time. No *Azolla* was present in the system.	
Macroinvertebrates	Macroinvertebrate community dominated by lowland taxa that are generally tolerant of poor water quality conditions. The abundance and diversity of macroinvertebrates is low throughout the system, but especially low downstream of Numurkah. The macroinvertebrate fauna is expected to be adversely affected by poor habitat quality and anthropogenic pollutants (Jacobs 2019). The severe and widespread hypoxic event associated with the spring 2022 floods caused a major impact to the macroinvertebrate community. Large numbers of dead freshwater shrimp were observed and shrimp were still absent from the system in mid January 2023, although yabbies were reported to have returned by mid January.	Declined in response to hypoxic flood conditions in 2022 – recovery trajectory is unknown.
Fish	In total, nine native and six exotic species have been recorded in lower Broken Creek. Katandra Weir in reach 1 recorded the highest diversity of native fish in 2021. Most native species tend to be patchily distributed along the creek, with the highest abundance of most species occurring at the most downstream weir pool sites (Reach 4). Murray cod, golden perch, Murray-Darling rainbowfish and Australian smelt are the most common native fish (Howson & Lloyd 2021). However, overall fish populations are dominated by non-native species; common carp (*Cyprinus carpio*), goldfish (*Carassius auratus*) and gambusia (*Gambusia holbrooki*). Of the larger bodied species, Murray cod (*Maccullochella peelii*) and golden perch (*Macquaria ambigua*) are regularly stocked into Broken Creek in large numbers. While there is some evidence of local spawning and recruitment for Murray cod (Jones et al. 2017), stocking is also likely to play a role in maintaining the relatively stable population numbers of these two species. Notably, neither species is detected regularly at sites in Reach 3 (i.e. between Nathalia and Numurkah, including the Numurkah weir pool), suggesting habitat quality in this reach is particularly poor. The 2022 autumn fish survey found a high relative abundance of Murray cod, Murray-darling rainbowfish and Australian smelt in the past two years as well as successful recruitment of these species. Years of higher abundance (Catch per Unit Effort -CPUE) were generally associated with years of (or following) elevated discharge, both in spring and summer; this included the years 2020 and 2021. There have been a number of fish kills in Broken Creek over the years, the most recent being in October 2022 following natural flooding. The large number of dead native fish (including Murray cod and golden perch) in spring 2022, followed by the extremely high numbers of juvenile carp observed to be entering the creek from the Murray River/Barmah Forest suggest the fish community has been	Declined in response to hypoxic flood conditions in 2022 – recovery trajectory is unknown.

Ecological value	Condition summary	Expected trajectory
	severely impacted by the 2022 flood event. This impact will be quantified in the autumn 2023 survey.	
Water quality	Suspended sediment (turbidity) is high, likely to be attributable to carp, catchment and bank erosion. Water quality data shows the creek also has high levels of nutrients and blue green algae outbreaks are common in warmer months. Hypoxic conditions, especially in response to blackwater events or during high summer temperatures, is a major issue. Dissolved oxygen levels were 0mg/L across the lower Broken Creek system for one week during the spring 2022 floods and have gradually recovered. Sediment chemistry indicates there is input of pollutants from the catchment and there is probably release of accumulated nutrients from the sediment to the water column during low oxygen conditions, that further fuels nutrient enrichment (Jacobs 2019).	Generally stable, with short periods of declining water quality in response to weather events. E.g. high unregulated inflows or summer heatwaves.

Shared benefits 2022-23

A review of the shared benefits associated with delivery of water for the environment in the lower Broken Creek and Nine Mile Creek over 2022-23 is provided below. As context, limited water for the environment has been delivered to lower Broken Creek so far in 2022-23 compared to previous years, due to the natural spring flooding i.e. deliveries in September 2022 (before the natural floods) and in summer (following the natural floods).

Table 11: Shared benefits from environmental water delivery along the lower Broken and Nine Mile Creeks 2022-23

Shared benefit	Beneficiary	Shared benefits in 2022-23
Cultural	Yorta Yorta Traditional Owners	During consultation with Yorta Yorta, specific cultural shared benefits were not identified from environmental water deliveries to the lower Broken and Nine Mile Creeks. However, environmental water deliveries align with their values of caring for country.
Amenity	General community, adjacent landholders, visitors	Environmental water deliveries helped restore water quality after the spring flooding. This included both the odour and appearance of creek water, which was severely impacted by the extended hypoxic blackwater event and had a detrimental impact on the amenity of towns such as Katamatite, Numurkah and Nathalia, as well as farms supplied by the creek i.e. domestic dams.
Recreation	Local residents, visitors, anglers, game hunters, kayakers and canoers.	Conditions conducive to recreation were restored through environmental water deliveries post the floods. The delivery of Goulburn Water Quality Reserve at select outfall locations (in between flood events), provided critical water quality refuge for native fish and became popular locations for local anglers.
Economic	Consumptive water users – GMW irrigators and diverters, Goulburn Valley Water (GVW).	During the floods, GVW was required to truck water in to maintain supply to Nathalia at great expense (as water quality was too poor to treat effectively to potable standards). Environmental water helped restore water quality after the flood and enable the water treatment plant to re-commence as soon as possible. Environmental water deliveries have continued to promote good water quality for local irrigators and D&S use. *Azolla* levels have remained very low.

Lessons and implications for 2023-24

Observations and monitoring along the lower Broken Creek system over 2022-23 highlighted the following points that will inform future watering and management actions:

- Provision of water quality refuge habitat through delivering small volumes of environmental water from outfalls is an effective way of minimising some of the impact of hypoxic conditions on native fish. Ideally, delivery through these outfalls should be continuous and commence prior to hypoxic conditions developing/arriving. However, commencing outfalls during a severe hypoxic event is still of benefit as observed in the 2022 event, where native fish located outfalls and accumulated there despite already experiencing several days of extremely low dissolved oxygen. i.e. a dozen native fish were surveyed using one outfall in reach 3 including Murray cod, golden perch and Murray darling rainbowfish. Once outfalls commence they should not be turned off prior to accumulated fish being salvaged, otherwise further fish deaths eventuate.
- In instances where flood conditions are present, outfall deliveries for water quality refuge can still be provided without exacerbating flooding, by taking into account the rate of water level recession against the minor flood level at designated locations and the travel time of outfall delivery arrival at these locations. Operational guidelines have been developed between GB CMA and GMW, with advice from key stakeholders, for such scenarios and will be similarly adopted in future flood years.
- Extremely high numbers of juvenile carp were observed entering lower Broken Creek (presumably from the flooded Murray River and Barmah Forest) in November 2022. This observation reflects previous investigations in Gunbower Forest that found once water temperature on the floodplain reach 16 deg C, there is 40 days until the new carp recruits begin migrating. Barmah Forest water temperature reached 16 deg C at the start of October and by 30 November there were significant migrations of carp observed well into reach 3. Further thought will be put into the opportunities in future flood years to increase head loss at Rices Weir fishway so small fish are unable to migrate into the creek (assuming the weir structure is not overtopped and Murray River water levels are low enough to create the required head loss).

Landscape scale considerations

The Lower Broken Creek is a tributary of the mid Murray system, connecting to the main Murray River channel near Barmah. It is one of many waterways (of varying sizes) that form a network of habitats available for migrating aquatic species that can travel large distances within the Murray-Darling Basin, particularly large-bodied native fish such as golden perch, Murray cod and silver perch.

As such, environmental water delivery in the lower Broken Creek considers how best to contribute to system-wide opportunities for native fish movement and breeding. In particular, the creek's discharge can be increased using environmental water during periods of fish migration to encourage a broader distribution of native species across the southern connected Basin by attempting to attract native fish into the creek from the Murray River.

There is an opportunity to provide a fish attractant flow in autumn each year, particularly where native fish are detected migrating up the Murray River. This was trialled in autumn 2022 and monitoring results are pending. This will help inform our understanding of what role lower Broken Creek plays in distributing native fish across the mid-Murray region.

Environmental objectives and scope of environmental watering

Environmental objectives for the lower Broken Creek and Nine Mile Creek have been documented in a variety of formats across multiple strategies and plans since 2001. The current environmental

objectives were developed through the recently completed Lower Broken Creek FLOWS study (Jacobs 2019; NRE 2002). The environmental objectives for the lower Broken and Nine Mile Creeks are summarised below, with further details available in Jacobs (2019).

Table 12: Environmental objectives for the lower Broken Creek and Nine Mile Creek

Ecological value	Long-term environmental objective
Native fish	1. Increase native fish abundance including the threatened Murray cod, golden perch and silver perch.
Native aquatic fauna	2. Maintain platypus, Rakali (water rat) and turtle populations, particularly outside the irrigation season.
Native vegetation	3. Reduce excessive build-up of *Azolla*. 4. Maintain and promote the cover and condition of native instream and littoral vegetation communities.
Macroinvertebrates	5. Maintain and promote the diversity and abundance of macroinvertebrates.
Water quality	6. Maintain dissolved oxygen levels suitable for aquatic animals.

The recommended flow components (potential watering actions) to achieve these objectives are shown below and previously in Tables 6-8. These have been developed noting that:

- many of the ecological values in the lower Broken and Nine Mile Creeks are in part or wholly reliant on aspects of the current, regulated water regime.
- delivery of environmental water to the lower Broken and Nine Mile Creeks can only occur via Shepparton and Murray Valley Irrigation District infrastructure, primarily during the irrigation season (approximately mid-August to mid-May) for larger flows, but that smaller deliveries may be made at other times.
- while there is spare channel capacity during the irrigation season to deliver current flow recommendations, this can be reduced during times of peak irrigation demand.

The potential watering actions outlined below are consistent with the FLOWS study (Jacobs 2019) and the Environmental Watering Plan (Water Technology 2010), with the following exceptions:

- The timing of fresh deliveries has been extended from the end of September to the end of November to account for the typical period when water temperatures reach 18 deg C, which is needed to encourage native fish movement (particularly golden perch). Water temperatures typically reach 18 deg C in mid to late October.
- The magnitude of the spring/summer/autumn low flow rate has been increased in reach 4 from 250 ML/d to 450 ML/d to provide adequate flows to maintain suitable DO levels over the hot summer period. A flow of 250 ML/d at Rices Weir does not appear adequate for preventing very low DO levels under warm water temperatures.
- The magnitude of the spring/summer/autumn low flow rate has been increased in reach 2 (Nine Mile Creek) from 150 ML/d to 250 ML/d to allow for the increased low flow rate in reach 4 to better manage low DO risks over the summer months. The additional water is required to be delivered through reach 2, as reach 1 is constrained in capacity (120 ML/d).

There is currently environmental research being conducted on lower Broken Creek and these watering actions may change during 2023-24 if scientific advice suggests amendments would lead to improved environmental outcomes. Any changes would be discussed with key stakeholders and require approval from the VEWH prior to implementation.

Table 13: Potential Watering Actions (reach 1)

Target reach: **Reach 1**	**Reach 1 is a priority to receive environmental water in 2023-24 as it provides different (flowing) habitat compared to downstream reaches, therefore increasing habitat diversity across the system. Reach 1 supports beds of *Vallisneria* and a range of aquatic species including platypus (historically), silver perch, Murray cod, golden perch and river blackfish. Lower Broken Creek experienced a severe hypoxic event in spring 2022. Delivery of environmental water will be critical to the system's recovery and will increase the success of other recovery efforts such as native fish stocking.** **Compliance point: Broken Creek diversion regulator at Katandra Weir**		
Potential watering action	Winter low flow (20-40 ML/d continuously, May to August)	Spring/summer/autumn low flow (70-120 ML/d continuously, August to May)	Freshes (1-3 freshes of 100-120 ML/d for 1-2 weeks, July to November)
Climate scenario variations	None	None	None
Triggers	None	Delivery of flow to reach 4 (flow rate is subject to water quality risk in downstream reaches and water availability). Delivery of water-in-transit i.e. IVT, Murray bypass.	Delivery of freshes to reach 4 (initial fresh to occur in July to help mobilise *Azolla* in downstream reaches (if necessary), follow up freshes to inundate littoral vegetation and encourage fish movement).
Environmental objectives	Increase native fish abundance including the threatened Murray cod, golden perch and silver perch. Maintain platypus, Rakali (water rat) and turtle populations, particularly outside the irrigation season. Maintain the cover and condition of native instream and littoral vegetation communities. Maintain the diversity and abundance of macroinvertebrates. Maintain dissolved oxygen levels suitable for aquatic species.	Increase native fish abundance including the threatened Murray cod, golden perch and silver perch. Maintain platypus, Rakali (water rat) and turtle populations, particularly outside the irrigation season. Maintain the cover and condition of native instream and littoral vegetation communities. Maintain the diversity and abundance of macroinvertebrates.	Increase native fish abundance including the threatened Murray cod, golden perch and silver perch. Maintain platypus, Rakali (water rat) and turtle populations, particularly outside the irrigation season. Maintain the cover and condition of native instream and littoral vegetation communities. Maintain the diversity and abundance of macroinvertebrates.
Expected watering effects	Maintain over-wintering habitat and instream refuge areas for native fauna including by providing sufficient water in Katandra Weir pool. Provide and improve habitat for fish species year-round in weir pools and habitats with flowing channels.	Increase availability of instream habitat for native fauna. Increase flow cues for fish movement and spawning. Provide soil moisture to improve the establishment and growth of native littoral vegetation.	Increase availability of instream habitat for native fauna. Increase flow cues for fish movement and spawning. Provide soil moisture to improve the establishment and growth of native littoral vegetation.

	Improve platypus carrying capacity and reduce predation risk, especially in Katandra Weir pool. Minimise exposure of turtles during winter dormancy. Maintain longitudinal connectivity to allow instream fauna to access food and shelter through providing sufficient water in flowing reaches. Maintain inundation of instream aquatic plants (e.g. *Vallisneria*) and prevent any periods of long-term drying, so they persist and provide food and cover for native fauna. Reduce stagnation of water in weir pools.	Inundate benches to promote the growth of instream aquatic species.	Inundate benches to promote the growth of instream aquatic species.
Rationale for delivery in 2023-24	Reach 1 is predominantly flowing habitat and the limited number of weir structures means flows must continue to maintain instream habitat. In the absence of winter low flow, pool habitats contract and become isolated, fringing habitats (littoral vegetation and woody habitat) become exposed and there is an overall contraction in available habitat for macroinvertebrates, fish and other aquatic biota. This potential watering action is a very high priority every year, to ensure minimum levels of instream habitat are provided to prevent impacts on aquatic values in this part of the creek.	The FLOWS study did not provide specific recommendations for spring/summer/autumn low flows in reach 1, but allowed for them to occur in response to local catchment runoff, climate conditions and in association with delivery of flow to reach 4. Such flows are expected to occur in reach 1 in 2023-24 (through the delivery of flow to reach 4) and are likely to provide the abovementioned benefits.	A managed spring fresh will be provided in reach 1 in 2023, in association with a managed fresh delivery to reach 4. This is a high priority in 2023-24 to help provide optimum conditions for recovery of aquatic fauna, post the spring 2022 hypoxic flood event.

Table 14: Potential Watering Actions (reach 2)

Target reach: **Reach 2**	**Reach 2 is a priority to receive environmental water in 2023-24 as it provides different (flowing) habitat compared to downstream reaches, therefore increasing habitat diversity across the system. Reach 2 supports beds of *Vallisneria* and a range of aquatic species including platypus (historically), Murray cod and Murray-Darling rainbowfish. There has been a substantial investment in restoring instream woody habitat to this reach. Lower Broken Creek experienced a severe hypoxic event in spring 2022. Delivery of environmental water will be critical to the system's recovery and will increase the success of other recovery efforts such as native fish stocking.** **Compliance point: Nine Mile Creek diversion regulator at Katandra Weir**		
Potential watering action	Winter low flow (20-40 ML/d continuously, May to August)	Spring/summer/autumn low flow (100-250 ML/d continuously, August to May)	Freshes (1-3 freshes of 100-200 ML/d for 1-2 weeks, July to November)
Climate scenario variations	None	None	None
Triggers	None	Delivery of flow to reach 4 (flow rate is subject to water quality risk in downstream reaches and water availability). Delivery of water-in-transit i.e. IVT, Murray bypass.	Delivery of freshes to reach 4 (initial fresh to occur in July to help mobilise *Azolla* in downstream reaches (if necessary), follow up freshes to inundate littoral vegetation and encourage fish movement).
Environmental objectives	Increase native fish abundance including the threatened Murray cod, golden perch and silver perch. Maintain platypus, Rakali (water rat) and turtle populations, particularly outside the irrigation season. Maintain the cover and condition of native instream and littoral vegetation communities. Maintain the diversity and abundance of macroinvertebrates.	Increase native fish abundance including the threatened Murray cod, golden perch and silver perch. Maintain platypus, Rakali (water rat) and turtle populations, particularly outside the irrigation season. Maintain the cover and condition of native instream and littoral vegetation communities. Maintain the diversity and abundance of macroinvertebrates.	Increase native fish abundance including the threatened Murray cod, golden perch and silver perch. Maintain platypus, Rakali (water rat) and turtle populations, particularly outside the irrigation season. Maintain the cover and condition of native instream and littoral vegetation communities. Maintain the diversity and abundance of macroinvertebrates.
Expected watering effects	Maintain over-wintering habitat and instream refuge areas for native fauna. Provide and improve habitat for fish species year-round in habitats with flowing channels. Improve platypus carrying capacity and reduce predation risk. Minimise exposure of turtles during winter dormancy.	Increase availability of instream habitat for native fauna. Increase flow cues for fish movement and spawning. Provide soil moisture to improve the establishment and growth of native littoral vegetation. Inundate benches to promote the growth of instream aquatic species.	Increase availability of instream habitat for native fauna. Increase flow cues for fish movement and spawning. Provide soil moisture to improve the establishment and growth of native littoral vegetation. Inundate benches to promote the growth of instream aquatic species.

	Maintain longitudinal connectivity to allow instream fauna to access food and shelter through providing sufficient water in flowing reaches. Maintain inundation of instream aquatic plants (e.g. *Vallisneria*) and prevent any periods of long-term drying, so they persist and provide food and cover for native fauna.		
Rationale for delivery in 2023-24	Reach 2 is predominantly flowing habitat and the limited number of weir structures (rock chutes), particularly upstream of Wunghnu, means flows must continue to maintain instream habitat. In the absence of winter low flow, pool habitats contract and become isolated, fringing habitats (littoral vegetation and woody habitat) become exposed and there is an overall contraction in available habitat for macroinvertebrates, fish and platypus. This potential watering action is a very high priority every year, to ensure minimum levels of instream habitat are provided to prevent impacts on aquatic values in this part of the creek.	The FLOWS study did not provide specific recommendations for spring/summer/autumn low flows in reach 2, but allowed for them to occur in response to local catchment runoff, climate conditions and in association with delivery of flow to reach 4. Such flows are expected to occur in reach 2 in 2023-24 (through the delivery of flow to reach 4) and are likely to provide the abovementioned benefits.	A managed spring fresh will be provided in reach 2 in 2023, in association with a managed fresh delivery to reach 4. This is a high priority in 2023-24 to help provide optimum conditions for recovery of aquatic fauna, post the spring 2022 hypoxic flood event.

Table 15: Potential Watering Actions (reach 3 and 4)

Target reach: **Reach 3 & 4**	**Reach 4 is a priority to receive environmental water in 2023-24 as it supports a relatively diverse native fish community including Murray cod and golden perch. This reach is shallow over large areas and highly regulated through a series of eight weirs. Consequently, it is prone to *Azolla* accumulations[3] and low dissolved oxygen, particularly during hot conditions. Poor water quality has contributed to several past fish death events. In spring 2022 the creek experienced a severe hypoxic event associated with natural flooding. Environmental water is critical for maintaining water quality, keeping fish ladders operational on each weir and promoting a robust native fish community. Delivery of environmental water will be critical to the system's recovery post the spring 2022 floods and will increase the success of other recovery efforts such as native fish stocking.** **Compliance point: Flow gauge at Rices Weir**		
Potential watering action	Winter low flow (40 ML/d continuously, May to August)	Spring/summer/autumn low flow (200-450 ML/d continuously, August to May)	Freshes (1-3 freshes of 300-450 ML/d for 1-2 weeks, July to November)
Climate scenario variations	None	None	None
Triggers	None	Flow rate considers water quality risk (*Azolla*, DO levels). A flow of 350 ML/d is targeted during summer and at other times with forecast high temperatures when risk of low DO is greatest. In the event of continued water quality decline at 350 ML/d (e.g. in association with unregulated inflows), higher flows (up to 450 ML/d) may be delivered for short periods to restore water quality.	Initial fresh in July dependent on *Azolla* levels. Follow up freshes consider: 1. the time since and frequency of previous freshes that provided suitable conditions for fish migration, spawning and dispersal. 2. whether the creek is recovering from a significant impact e.g. hypoxia causing fish deaths. 3. water temperature (min 18 deg C for optimum fish movement – typically 15th October). 4. water quality risk (*Azolla*, DO levels).
Environmental objectives	Increase native fish abundance including the threatened Murray cod, golden perch and silver perch. Maintain platypus, Rakali (water rat) and turtle populations, particularly outside the irrigation season. Maintain the cover and condition of native instream and littoral vegetation communities.	Increase native fish abundance including the threatened Murray cod, golden perch and silver perch. Maintain platypus, Rakali (water rat) and turtle populations, particularly outside the irrigation season. Maintain the cover and condition of native instream and littoral vegetation communities.	Increase native fish abundance including the threatened Murray cod, golden perch and silver perch. Maintain platypus, Rakali (water rat) and turtle populations, particularly outside the irrigation season. Maintain the cover and condition of native instream and littoral vegetation communities.

[3] Significant *Azolla* accumulations have occurred in 2002-03, 2007-08, 2008-09, 2015-16 and 2017-18.

	Maintain the diversity and abundance of macroinvertebrates. Maintain dissolved oxygen levels suitable for aquatic animals.	Maintain the diversity and abundance of macroinvertebrates. Reduce excessive build-up of *Azolla*. Maintain dissolved oxygen levels suitable for aquatic animals.	Maintain the diversity and abundance of macroinvertebrates. Reduce excessive build-up of *Azolla*. Maintain dissolved oxygen levels suitable for aquatic animals.
Expected watering effects	Maintain over-wintering habitat and instream refuge areas for native fauna (through sufficient water in weir pools). Maintain longitudinal connectivity to allow instream fauna to access food and shelter and escape hypoxic events (through continual fishway operation and sufficient water in flowing sections and weir pools). Improve platypus carrying capacity and reduce predation risk. Provide opportunities for platypus movement between upper reaches and the Murray River. Minimise exposure of turtles during winter dormancy. Maintain inundation of instream aquatic plants (e.g. *Vallisneria*) and prevent any periods of long-term drying, so they persist and provide food and cover for native fauna. Reduce stagnation of water in weir pools.	Increase availability of instream habitat for native fauna. Increase flow cues for fish movement and spawning. Provide soil moisture to improve the establishment and growth of native littoral vegetation. Inundate benches to promote the growth of instream aquatic species. Increase mobilisation of *Azolla* accumulations. Reduce stagnation of water in weir pools.	Increase availability of instream habitat for native fauna. Increase flow cues for fish movement and spawning. Provide soil moisture to improve the establishment and growth of native littoral vegetation. Inundate benches to promote the growth of instream aquatic species. Increase mobilisation of *Azolla* accumulations. Reduce stagnation of water in weir pools. Note: flows over 300 ML/d can flush *Azolla* whilst it is still in single layers or individual plants. Flushes up to 450 ML/d disperse large blooms.
Rationale for delivery in 2023-24	In the absence of winter low flow, pool habitats contract and become isolated, fringing habitats (littoral vegetation and woody habitat) become exposed, fishways cease operation and there is an overall contraction in available habitat and connectivity for macroinvertebrates, fish and other aquatic species. This potential watering action is a very high priority every year, to ensure minimum levels of instream habitat and connectivity are provided to prevent impacts on aquatic values in this part of the creek.	Spring/summer/autumn low flows help mobilise *Azolla* in the main flow path and reduce excessive build up. While *Azolla* levels have remained low since August 2020, it needs continual management through flow manipulation to prevent large accumulations. Spring/summer/autumn low flows are also essential for maintaining suitable DO levels over the warmer months when water temperature increases and dissolved oxygen levels decline in response. This is an important pro-active management action that reduces the risk of fish death events.	Following the spring 2022 hypoxic flood event and associated fish deaths, a managed spring fresh is a priority to deliver in 2023-24 to help provide optimum conditions for recovery of aquatic fauna in reach 4.

Scenario planning and prioritisation

Water resource outlook for 2023-24

The continuation of La Niña conditions in 2022-23 resulted in storages being at capacity from mid-September 2022 through to the end of January 2023 (Table 16).

According to the Bureau of Meteorology (climate outlook for February to May 2023), the seasonal rainfall outlook for March to May does not strongly favour above or below average rainfall across northern Victoria. Regardless of the uncertainty around autumn inflows, the very high storage levels indicate a strong water resource position in both the Goulburn and Murray systems for 2023-24.

Table 16: Murray and Goulburn storage levels in recent years (late summer)

Storage	2020	2021	2022	2023
Lake Eildon	36%	62%	84%	99%
Hume Dam	14%	53%	96%	96%
Dartmouth Dam	47%	63%	93%	99%

Source: Storage Levels - Goulburn Murray Water (g-mwater.com.au)

Early forecasts predict strong opening allocations (1 July) for the Goulburn and Murray systems under all scenarios (Table 17), with 100% allocations expected in both systems by mid-October 2023 under all but the extreme dry scenario.

Table 17: Goulburn and Murray system outlook for seasonal determination of high reliability shares

Inflow Conditions	3 July 2023	15 August 2023	16 October 2023	15 February 2024
Goulburn System				
Wet	100%	100%	100%	100%
Average	92%	100%	100%	100%
Dry	79%	95%	100%	100%
Extreme Dry	75%	80%	87%	97%
Murray System				
Wet	100%	100%	100%	100%
Average	100%	100%	100%	100%
Dry	86%	95%	100%	100%
Extreme Dry	82%	82%	82%	88%

Source: G-MW, 15 February 2023

Carryover is also available in environmental accounts and is estimated at more than 300 GL (Kris Leckie, pers. comm. Broken EWAG meeting 13 February 2023). As a result, even under the extreme dry climate scenario, it is expected that there will be sufficient environmental water available to meet the lower Broken and Nine Mile Creek environmental flow requirements in 2023-24.

Furthermore, delivery of water in transit through the lower Broken Creek could occur (e.g. IVT/Murray Bypass), which will reduce the volume of environmental water required to meet flow targets. Except for 2021-22 and 2022/23, approximately 30,000 ML of IVT and over 15,000 ML of Murray bypass flow has been delivered to lower Broken Creek in recent years. Under the Goulburn to Murray Trade Rule Operating Plan, approximately 8 GL/month (~265 ML/d) of IVT is assumed to be delivered through lower Broken Creek over November to April. Murray bypass flows would be in

addition to this volume. The lower Broken Creek system is therefore in a secure water resource position for 2023-24.

Scenario Planning

Typically, scenario planning involves taking account of variations in water availability across climate scenarios (ranging from extreme dry to wet) and differing ecological goals (ranging from protection to enhancement) to identify the most appropriate potential watering actions for each scenario.

However, the lower Broken Creek system differs to many other environmental water locations in that the environmental flow needs are relatively fixed from year to year i.e. are largely independent of annual climatic conditions. This makes the standard scenario planning process less applicable.

Firstly, most of the water in the lower Broken Creek system is sourced from the Murray and Goulburn Rivers through regulating structures. Catchment runoff may contribute short flow peaks in winter and spring, but does not significantly contribute to environment flow needs apart from very wet years. However, even in wet years the potential watering actions may not change. E.g. the timing of natural freshes may occur later in the year after managed freshes have already been delivered, or flow may be required to restore dissolved oxygen levels in the creeks after flood waters pass. Potential watering actions therefore remain consistent across each scenario, although their timing and purpose may change from year-to-year depending on the conditions.

Secondly, the volume of water expected to be available to lower Broken Creek in 2023-24 far exceeds that required to meet environmental flow requirements, even under an extreme dry scenario (Table 18). This means the potential watering actions don't need to be modified to account for a lack of available water. They are instead delivered through a combination of different water sources including environmental water, IVT, Murray bypass and unregulated inflows.

The lack of constraining factors and therefore consistency in potential watering actions across climate scenarios, means the ecological goal for delivering environmental water in lower Broken Creek has a strong focus on recovery, and where possible, enhancement (while acknowledging the limitations posed by being a regulated, working creek). This includes improving recruitment opportunities and the health and resilience of the system, rather than just maintaining it. For this reason, the lower Broken Creek is also a good candidate for complimentary measures.

Despite the consistency in potential watering actions, the actual management of water through the season needs to be adaptive and flexible, with water delivery decisions adjusting as the season unfolds, particularly in response to the variable flow needs of *Azolla* and dissolved oxygen management.

Table 18: Scenario planning summary

Reach 3	Scenario 1 Extreme dry 99% POE	Scenario 2 Dry 90% POE	Scenario 3 Average 50% POE	Scenario 4 Wet 10% POE
Expected climatic and flow conditions	Very low rainfall results in no natural catchment runoff in winter and no unregulated flows at Rices Weir. Water sources available: • Up to 48,000 ML of IVT[4] (30,000 ML delivered to lower Broken in recent years) • Estimated 10,000+ ML Murray bypass (variable in recent years) • 30,000 ML Goulburn Water Quality Reserve • Up to 50,000 ML of CEW/VEWH (depending on allocations) 88% Murray and 97% Goulburn high reliability allocations	Some winter rainfall results in flows of 18-20 ML/day past Rices Weir in July generated from natural catchment runoff. Water sources available: • Up to 48,000 ML of IVT[4] (30,000 ML delivered to lower Broken in recent years) • Estimated 10,000+ ML Murray bypass (variable in recent years) • 30,000 ML Goulburn Water Quality Reserve • Up to 50,000 ML of CEW/VEWH (depending on allocations) 100% Murray and Goulburn high reliability allocations	Average rainfall over the season results in flows of 25 ML/day from July to September past Rices Weir, with a 700-900 ML/day fresh and some 200-300 ML/day freshes. Flows generated from natural catchment runoff. Water sources available: • Up to 48,000 ML of IVT[4] (30,000 ML delivered to lower Broken in recent years) • Estimated 10,000+ ML Murray bypass (variable in recent years) • 30,000 ML Goulburn Water Quality Reserve • Up to 50,000 ML of CEW/VEWH (depending on allocations) 100% Murray and Goulburn high reliability allocations	High rainfall results in flows of 250+ ML/day from July to October past Rices Weir, with a 2,500-3,000 ML/day high flow and 5,000 ML/day fresh. Flows generated from natural catchment runoff. Water sources available: • Up to 48,000 ML of IVT[4] (30,000 ML delivered to lower Broken in recent years) • 30,000 ML Goulburn Water Quality Reserve • Up to 50,000 ML of CEW/VEWH (depending on allocations) 100% Murray and Goulburn high reliability allocations
Tier 1 Potential Watering Actions	Winter low flow (40 ML/d continuously, May to August) Spring/summer/autumn low flow (200-450 ML/d continuously, August to May). Freshes (1-3 freshes of 300-450 ML/d for 1-2 weeks, July to November).	Winter low flow (40 ML/d continuously, May to August) Spring/summer/autumn low flow (200-450 ML/d continuously, August to May). Freshes (1-3 freshes of 300-450 ML/d for 1-2 weeks, July to November).	Winter low flow (40 ML/d continuously, May to August) Spring/summer/autumn low flow (200-450 ML/d continuously, August to May). Freshes (1-3 freshes of 300-450 ML/d for 1-2 weeks, July to November).	Winter low flow (40 ML/d continuously, May to August) Spring/summer/autumn low flow (200-450 ML/d continuously, August to May). Freshes (1-3 freshes of 300-450 ML/d for 1-2 weeks, July to November). *
Tier 1 Demands	**Total: 91,100 ML** • Winter low flow – 4,090 ML	**Total: 91,100 ML** • Winter low flow – 4,090 ML	**Total: 91,100 ML** • Winter low flow – 4,090 ML	**Total: 91,100 ML** • Winter low flow – 4,090 ML

[4] Based on 8GL/mth from November to April (Operating Plan for Delivery of Water from the Goulburn IVT Account 2021-22).

Reach 3	Scenario 1 Extreme dry 99% POE	Scenario 2 Dry 90% POE	Scenario 3 Average 50% POE	Scenario 4 Wet 10% POE
	• Spring/summer/autumn low flow – 76,615 ML • Freshes - 10,400 ML	• Spring/summer/autumn low flow – 76,615 ML • Freshes - 10,400 ML	• Spring/summer/autumn low flow – 76,615 ML • Freshes - 10,400 ML	• Spring/summer/autumn low flow – 76,615 ML • Freshes - 10,400 ML
Estimated ewater required for Tier 1^	< 50,000 ML	< 50,000 ML	< 50,000 ML	> 50,000 ML
Tier 2 Potential Watering Actions	-	-	-	-
Tier 2 Demands (ML)	-	-	-	-
Carryover requirements	86,500 ML to secure the following high priority Potential Watering Actions for 2024/25: • Winter low flow (40 ML/d mid May-mid August) – 4,090 ML • Spring/summer/autumn low flow (250 ML/d spring, 350 ML/d summer, 200-250 ML/d autumn) – 82,390 ML Securing low flow volumes will ensure the health of the creek is maintained (e.g. habitat is not lost, fishways continue to function and poor water quality is avoided), particularly in years when water-in-transit deliveries are limited.			

* Freshes are likely to be met by unregulated flows under a wet scenario, but may still be required depending on the timing and extent of unregulated flows and the presence of *Azolla* accumulations.

^Accounting for other expected flows.

Delivery constraints

Constraints in the irrigation network

The Broken Creek system has no environmental entitlements or water storages. Therefore, all environmental water must be delivered via irrigation channels from the Murray River or the Goulburn River.

Given the flow needs of the lower Broken and Nine Mile Creeks are small relative to the water resources available to meet them from the Murray and Goulburn systems, the ecological needs of the creeks are generally not constrained by resource availability. However, they are constrained by the availability of spare channel capacity to deliver environmental water when irrigation demand is high, as the environment does not hold delivery shares in these systems and is therefore subject to interruptible supply (systemic constraint). Outside of the irrigation season, infrastructure maintenance by GMW over winter may also limit the ability to deliver environmental water (temporary constraint).

There are 10 channels that outfall to the lower Broken and Nine Mile Creeks that collectively can supply approximately 570 ML/d (170 ML/d from the Murray Irrigation District and up to 400 ML/d from the Shepparton Irrigation District). However, this is reduced during times of peak irrigation demand (often in spring and autumn). As a result, the estimated volumes (in Table 19) to meet the environmental objectives for the lower Broken and Nine Mile Creeks may not be delivered. Historic annual environmental water deliveries to this system have ranged from 30,000 ML to 70,000 ML.

Given the capacity constraints in the channel network, the proposal aims to have water delivered from both the Goulburn and Murray Rivers at the same time to maximise use of the spare channel capacity for environmental water deliveries. However, Goulburn environmental water entitlement needs to be supplied to the lower Broken Creek from the Goulburn supply system in the months when Goulburn Inter-Valley Transfers are either not occurring or are low (as Goulburn IVT has a limited period in which it can be delivered which depends on seasonal conditions and Murray system supply needs).

In addition, if required to alleviate *Azolla* accumulations, a fresh will be delivered down the lower Broken and Nine Mile Creeks in late winter to flush the *Azolla,* before irrigation demand significantly increases in spring and reduces environmental water delivery opportunities.

Flooding private land

Low lying land in reach one means that flows over 120 ML/day can create minor flooding of private land. GMW manage the Katandra weir and the Broken creek regulator at the top of this section to maintain flows below 120 ML/day by sending most flow down Nine Mile Creek (Reach 2).

Delivery of environmental water is not constrained by the risk of flooding private and public assets as the maximum volume able to be delivered (around 500 ML/day) represents a small proportion of the total capacity of the creeks downstream of the environmental water outfall locations (around 2,000ML/day) and GMW can actively manage flows to prevent out of channel flows.

Farm drains along Nine Mile Creek

Several farm drains exist along Nine Mile Creek to enable private land to drain to the creek under wet conditions. Currently, GMW opens these drains over winter and closes them with stopbanks when the risk of wet conditions passes.

During environmental water deliveries in August 2020 these drains remained open (due to the forecast wet conditions) and they received environmental water from the creek as water levels increased. Some of this water was harvested by the landowners as permitted under their drainage licenses. While the stopbanks had been partially re-instated by the start of September 2020, the flow into Nine Mile Creek during the spring fresh delivery in mid-September was constrained to 150 ML/d

to prevent the drains re-engaging and further loss of water. The drains were fully re-instated in time for higher IVT deliveries in mid-November.

Fortunately, the constraint did not impede the ability to meet the spring fresh flow target (100-200 ML/d) in reach 2. GMW have advised there is a long-term plan to install infrastructure (e.g. one-way stop valves) to eliminate this temporary constraint.

Confounding factors

The lower Broken Creek system is highly modified and has been subject to multiple pressures over many decades. As a result, it was rated as having poor to moderate condition (in the last Index of Stream Condition assessment, 2010). Below are the key confounding factors that continue to hinder achievement of the long-term environmental objectives for the system and what mitigating actions are currently planned.

Table 19: Confounding factors hindering achievement of environmental objectives

Long-term environmental objective	Confounding factors	Mitigating actions planned*
1. Increase native fish abundance including the threatened Murray cod, golden perch and silver perch.	Poor instream habitat (e.g. large woody debris, aquatic macrophytes) hinder the provision of nesting sites (e.g. for Murray cod), shelter and food. The lack of macroinvertebrate food resources for fish, turtles and platypus (related to a lack of instream habitat) is one of four main factors limiting the ecological health of the system (Jacobs 2019).	Re-instating snags (ongoing through GB CMA). Instream planting of aquatic native species (GB CMA). Reinstating deep pools through sediment removal (GB CMA). Translocation of threatened freshwater catfish (GB CMA through the MDBA Native Fish Recovery Strategy).
	Weir pools limit hydrodynamic diversity, especially flowing habitat (>0.4m/s) that is important for in-channel, flow-dependent specialists such as golden perch and silver perch to migrate and spawn.	None – the highly regulated nature of lower Broken Creek (particularly reach 4) limits the ability to provide flowing habitat at velocities preferred by large-bodied fish. Velocity measurements indicate maximum flows of 0.3m/s under higher flows and with weir pool drawdown. Velocities in the flowing sections upstream are also low, being limited by the very low gradient.
	Instream barrier at Kokoda Road – the road culvert provides dark and shallow conditions that are not conducive to fish movement.	Moira Shire has been notified of the opportunity to improve this structure.
	Functionality of Rices Weir fishway is limited. It relies on an adequate level of backwater being available from the Murray River, which is difficult to achieve under low Murray River flow conditions.	Issue identified in the Mid Murray Floodplain Recovery Reach fish recovery plan (ARI 2021). There are no current plans to upgrade the structure.
2. Maintain platypus, Rakali (water rat) and turtle populations, particularly outside the irrigation season.	Poor instream habitat (e.g. large woody debris, aquatic macrophytes) hinder the provision of shelter and food. The lack of macroinvertebrate food resources for fish, turtles and platypus (related to a lack of instream habitat) is one of four main factors limiting the ecological health of the system (Jacobs 2019).	Re-instating snags (ongoing through GB CMA). Instream planting of aquatic native species (GB CMA). Investigating how to improve flow delivery to minimise bank erosion (GB CMA).

Long-term environmental objective	Confounding factors	Mitigating actions planned*
	For platypus, some of the other factors limiting the distribution and abundance include (Jacobs 2019): - dredged and re-aligned channels. - lack of instream woody habitat. - increased bank and bed erosion. - increased sedimentation of deep pools. - the low-lying nature of the banks, which means high flows in late spring and summer may inundate nests and drown young.	
3. Reduce excessive build-up of *Azolla*.	None identified – currently being achieved through ongoing flow management.	-
4. Maintain and promote the cover and condition of native instream and littoral vegetation communities.	Regulated flows continue to transport fine sediment through the water column, contributing to high levels of turbidity, which may be impacting on the health of macrophytes by limiting light penetration (Jacobs 2019). The diversity of instream vegetation is limited in many parts of the system. Stable water levels (especially during the irrigation season) limit the cover and health of littoral vegetation.	Instream planting of aquatic native species (GB CMA). Investigating opportunities to increase water level variability to improve the recruitment and growth of littoral vegetation (GB CMA). Monitoring has commenced under the Goulburn to Murray Trade Rule Monitoring Program and additional water level analyses are being conducted by scientists through the GB CMA.
5. Maintain and promote the diversity and abundance of macroinvertebrates.	Poor instream habitat (e.g. large woody debris, aquatic macrophytes) hinder the provision of shelter and food. A lack of habitat (i.e. large woody habitat) is likely to be the most limiting factor effecting freshwater prawn abundance in the system (Jacobs 2019).	Re-instating snags (ongoing through GB CMA). Instream planting of aquatic native species (GB CMA). Investigating opportunities to increase water level variability to improve the recruitment and growth of littoral vegetation.
6. Maintain dissolved oxygen levels suitable for aquatic animals.	Large areas of shallow water in the weir pools are more inclined to heat up under high ambient temperatures and therefore have reduced dissolved oxygen. Lentic conditions (<0.4m/s) provide little opportunity for oxygenation through turbulence. Limited aquatic plants reduce the opportunity for oxygenation through photosynthesis.	Instream planting of aquatic native species (GB CMA). Continued delivery of adequate summer flow rates, especially during high temperatures.
Various objectives	Erosion from regulation and weirs leading to channel widening and shallowing (potentially accelerated through consistently high water-in-transit deliveries). This reduces the quality of instream habitat (physical form, water quality) for native aquatic fauna.	Investigating opportunities to reduce the rate of erosion (GB CMA). Monitoring has commenced under the Goulburn to Murray Trade Rule Monitoring Program and additional water level analyses are being conducted by scientists through the GB CMA.

* Subject to funding

Increasing knowledge

The key knowledge gaps related to each environmental objective are outlined below.

Table 20: Key knowledge gaps for lower Broken Creek and Nine Mile Creek

Long-term environmental objective	Knowledge gap	Implications and planned monitoring
1. Increase native fish abundance including the threatened Murray cod, golden perch and silver perch.	Evidence of migration, spawning events and recruitment following specific flows. How weir pool manipulation (water level rise) in conjunction with fresh delivery could optimise flow cues for native fish. How carp respond to different flow components. How head loss through Rices Weir could be increased at times of high juvenile carp immigration to prevent access to the creek. Fish movement patterns in the absence of winter low flow i.e. refuge locations.	Regular fish surveys are required to enable adaptive management of watering actions and identify whether progress is being made towards the long-term environmental objective. An autumn fish survey was conducted in 2021 and 2022. An autumn fish survey is planned for autumn 2023 under the Goulburn to Murray Trade Rule Monitoring Program. Other research opportunities are subject to funding.
2. Maintain platypus, Rakali (water rat) and turtle populations, particularly outside the irrigation season.	Current status of platypus, Rakali and turtles – abundance and distribution.	In the absence of surveys, it is unknown whether populations are stable and whether over-wintering habitat provided through current winter low flows is adequate for these species. No surveys are planned in the near future.
3. Reduce excessive build-up of *Azolla*.	None identified.	Regular monitoring of *Azolla* levels (particularly in reach 4) will continue (GB CMA, GMW).
4. Maintain and promote the cover and condition of native instream and littoral vegetation communities.	If and how the cover and condition of native instream and littoral vegetation is changing. What flows provide optimum conditions for native vegetation, particularly in the littoral zone. Whether consistent high flows associated with water-in-transit deliveries are impacting littoral vegetation.	Regular vegetation monitoring is needed to determine progress against the long-term objective and enable adaptive management of watering actions, particularly any risks associated with consistently higher flows. An autumn bank vegetation survey was conducted in 2022 and follow-up autumn surveys are planned under the Goulburn to Murray Trade Rule Monitoring Program.
5. Maintain and promote the diversity and abundance of macroinvertebrates.	If and how the diversity and abundance of macroinvertebrates is changing, especially given recent hypoxic events. How the macroinvertebrate community is recovering from hypoxic events.	In the absence of surveys, it is unknown whether the macroinvertebrate community is being maintained. Given this is a key food resource for fish, turtles and platypus, it is also unknown whether the macroinvertebrate community is limiting the ecological health of the system. The last survey was completed in 2015-16. No surveys are planned in the near future.
6. Maintain dissolved oxygen levels suitable for aquatic animals.	Why Rices Weir pool is prone to lower DO levels compared to other weir pools in reach 4.	Regular monitoring of dissolved oxygen levels (particularly in reach 4) will continue (GB CMA, GMW).

Risk Management

Each year the environmental water holders facilitate a risk workshop and develop a table of risks associated with environmental water delivery in northern Victoria. Risks associated with the proposed water delivery in the lower Broken Creek and Nine Mile Creek are shown in Table 21. Risks identified for other systems not relevant to this proposal have been removed and so the risk numbering is not sequential. Mitigation strategies that will be employed by the GB CMA to address the high and medium risks are identified.

Legend for Table 23:

1. Risk category abbreviations are: Env. – environment/sustainability; BC – business cost; People – safety/wellbeing and people/culture; Rep – political/reputation; Legal – legal consequence; Service – service delivery; CH – cultural heritage
2. L refers to the Likelihood of a risk occurring. Abbreviations for consequence ratings are: AC – almost certain; L – likely; P – possible; U – unlikely
3. C refers to the Consequence if the risk occurs. Abbreviations for consequence ratings are: Min – minor; Mod – moderate; Maj – major; Ext - extreme

Table 21: Risk assessment of proposed water delivery

No.	Risk category[1]	Risk description	L[2]	C[3]	Risk rating	Mitigation actions	Lead organisation for action
1	Env	Specified flow rates are insufficient to achieve the intended extent of wetland inundation or magnitude and duration of river flows, resulting in a failure to achieve planned environmental outcomes.	P	Maj	Medium	Include contingency allowance in estimated watering requirements, based on previous event data, and consider a contingency in the duration of the event to achieve desired wetland inundation. Monitor event (especially for deliveries to new sites or for previously untested events) and adjust flows as necessary, or terminate event if it becomes clear that insufficient water is available. Identify and address constraints that may limit the flow rates for environmental deliveries.	CMA CMA CMA/GMW

No.	Risk category[1]	Risk description	L[2]	C[3]	Risk rating	Mitigation actions	Lead organisation for action
2	Rep	Specified flow rates are insufficient to achieve the intended extent of wetland inundation or magnitude and duration of river flows, resulting in a failure to achieve planned environmental outcomes and loss of community support.	P	Maj	Medium	Communications on the environmental benefits of watering actions. Monitor event (especially for deliveries to new sites or for previously untested events) and adjust flows as necessary, or terminate event if it becomes clear that insufficient water is available. Communicate the need for complimentary measures to optimise the benefits of environmental watering actions.	CMA CMA CMA
3	Env	Overestimates of environmental water demand prevents planning for supplying demands at other locations. Note: Planning watering actions also includes decisions around the carryover and trade of water as alternatives to current year water use decisions.	P	Min	Low	CMAs review demand estimates and targets met by unregulated flows throughout the delivery cycle and regularly advise VEWH of any changes so unused water can be reallocated. CMAs review demand estimates at the conclusion of the watering year, prior to the development of the following seasonal watering proposal, so estimates of future requirements are more accurate. River operators provide regular updates on flows, including through OAG meetings. Manage Water Holdings to maximise supply opportunities for all sites.	CMA CMA MDBA/GMW VEWH
4	Env	Inaccurate accounting and measurement or operational error results in target flows either not being achieved or being exceeded, leading to a failure to achieve planned environmental outcomes.	U	Mod	Low	Review accounting and measurement processes to be used to ensure that techniques are agreed and monitoring/measurement sites are operational.	GMW

No.	Risk category[1]	Risk description	L[2]	C[3]	Risk rating	Mitigation actions	Lead organisation for action
5	BC	Volumes of environmental water delivered or released exceed volumes approved for use in the event, leading to potential overdrawing of accounts or preventing other planned actions being undertaken. Note: Planning watering actions also includes decisions around the carryover and trade of water as alternatives to current year water use decisions.	U	Maj	Low	Ensure that deliveries are reported progressively throughout the event and are monitored against ordered volume. Ensure ordering and delivery procedures are kept up-to-date and adhered to. Ensure metering and reporting processes for temporary pump operations are suitable and effective.	CMA GMW GMW/CMA VEWH CMA
6	Env	Environmental water account is overdrawn, leading to water not being available as per approved watering statement to complete planned actions and environmental benefits not being achieved. Note: Planning watering actions also includes decisions around the carryover and trade of water as alternatives to current year water use decisions.	U	Maj	Low	Monitor ABA balances and undertake regular communications with CMA and RWC as part of portfolio management activities. Ensure that deliveries are reported progressively throughout the event and are monitored against ordered volume.	VEWH CMA/GMW
7	Env	Planned maintenance of water delivery infrastructure results in planned/specified flows not being achieved, leading to a failure to achieve planned environmental outcomes.	L	Min	Low	Undertake early planning and communications between the CMA and storage operator to minimise likelihood of constraints, enable scheduling of maintenance outside of high demand periods or identify alternative environmental water delivery windows to avoid scheduled maintenance activities. Consider adding time contingencies to planned maintenance schedules to ensure works are completed prior to commencement of watering actions.	CMA/GMW CMA

No.	Risk category[1]	Risk description	L[2]	C[3]	Risk rating	Mitigation actions	Lead organisation for action
8	Env	Failure of poorly maintained environmental delivery infrastructure results in planned/specified flows not being achieved, reducing the ability to achieve planned environmental outcomes (including failure or damage due to vandalism).	L	Mod	Medium	Asset ownership is clarified and the asset owners perform regular maintenance, and pre-event asset inspections, on delivery infrastructure. **Note that insufficient resources are likely to limit the asset owner's ability to regularly inspect and maintain infrastructure. Increased resources for these activities may further reduce the likelihood and risk ratings.* Report vandalism to police. Review asset design to minimise opportunities for interference or damage. For privately owned assets, arrange approvals to use/operate assets and undertake pre-delivery inspections. Communicate failures to the CMA. Initiate documentation of asset ownership and management arrangements in national parks. Consider monitoring options to detect vandalism, interference or failure of assets at individual sites with elevated risk.	Asset owner Asset owner Asset owner CMA Asset owner PV Asset owner
9	Env	Poor condition of delivery infrastructure results in the asset owner being unable to operate the structure due to OH&S risks, leading to failure to deliver environmental flows and to achieve environmental objectives. Note: This issue may affect multiple sites.	L	Mod	Medium	Asset owner to undertake regular maintenance and pre-event asset inspections on delivery infrastructure. **Note that insufficient resources are likely to limit the asset owner's ability to regularly inspect and maintain infrastructure. Increased resources for*	Asset owner

No.	Risk category[1]	Risk description	L[2]	C[3]	Risk rating	Mitigation actions	Lead organisation for action
		GMW to confirm OH&S status and likelihood rating.				*these activities may further reduce the likelihood and risk ratings.* Communicate failures to the CMA Develop design for new regulating structure and seek funding to implement necessary upgrades in conjunction with asset owner. Note: PV proposing to issue operating licences for BMF regulators.	Asset owner CMA (MDBA in Barmah Forest)
10	Env	High operational and consumptive water demands lead to reduced access for environmental deliveries, with the result that target flows/volumes cannot be achieved, impacting on environmental outcomes.	L	Min	Low	Event planning will seek to avoid peak demand periods, and events will be monitored and adjusted as necessary. System operators to provide longer term forecasts for future consumptive demands as an input to planning watering proposals Develop longer term agreements on river capacity access for environmental deliveries. Investigate opportunities to undertake deliveries outside the irrigation season with consideration of appropriate delivery costs	CMA/GMW GMW/MDBA VEWH CMA/VEWH
11	Env	High downstream demands may lead to flows that exceed local environmental requirements and targets (including rates of river rise and fall), leading to negative environmental outcomes, including negating previous environmental improvements.	AC	Maj	Extreme	Monitor the effectiveness of adopted seasonal flow limits for river systems, with annual negotiation and management of release plans and reviews during the season as required. Monitor impacts of new trade limits and revised operating rules and review as necessary.	VEWH/ DEECA DEECA/ GBCMA

No.	Risk category[1]	Risk description	L[2]	C[3]	Risk rating	Mitigation actions	Lead organisation for action
						Coordination of downstream e-water demands with regard for upstream impacts to balance impacts and benefits.	VEWH/ SCBEWC
12	Legal	Environmental releases, either on their own or potentially in combination with unexpected tributary inflows, cause unauthorised inundation of private land, resulting in impacts on landowner activities and assets.	P	Maj	Medium	Ensure currency of any landholder agreements for inundation of private land. Release plans designed to avoid overbank flows or unauthorised flooding. Monitor events and adjust releases to avoid overbank flows. This may include limiting deliveries to daylight hours only. Monitor forecast rainfall and tributary inflows and adjust releases to avoid overbank flows. Monitor deliveries to new locations to build an understanding of flow patterns and inundation thresholds and adjust releases accordingly.	CMA CMA GMW/MDBA GMW/MDBA CMA
18	Env	Environmental water deliveries result in low dissolved oxygen (DO) levels, with adverse environmental impacts. Note: Advice is that annual leaf litter accumulation is sufficient to cause risk, even if previously inundated.	U	Mod	Low	Where possible implement a full annual suite of flow components in river systems, including those designed to control build of organic matter (such as winter flushes). Plan deliveries with consideration of high temperature periods where appropriate. Develop monitoring and response plans and reserve contingency volumes in delivery plans for dilution flows if DO concentrations drop to levels of concern. Monitor leaf litter loads and avoid exceeding any flow thresholds likely to create hypoxic black water	CMA CMA

No.	Risk category[1]	Risk description	L[2]	C[3]	Risk rating	Mitigation actions	Lead organisation for action
						events, where possible and considering temperature drivers. Assess new/proposed actions for DO impact potential and adjust watering plans as needed.	CMA
19	Rep	Environmental water deliveries result in low DO levels, with adverse environmental impact and loss of community support.	U	Maj	Low	Communicate benefits of environmental water management to the broader community and engage with recreational user peak bodies and management agencies. Communicate the benefits of environmental water management and inform the local community of environmental water management activities and the underlying rationale, including blackwater mitigations. Inform communities of black water vs hypoxic black water issues, to build understanding and support.	VEWH CMA VEWH/CEWO
20	Env	Environmental water deliveries may generate or mobilise BGA blooms, with adverse water quality and/or health impacts (including to people, livestock and pets), resulting in cessation of releases and environmental impacts.	P	Maj	Medium	Consider likelihood of initiating BGA blooms in event planning and amend as required to manage risk, including investigating alternate delivery paths - e.g. lower outlets/offtakes, or non-delivery (e.g. as per 2022 for lower Broken creek). Land managers or water corporation implement a monitoring program during environmental watering events, and where issues are identified, activate BGA response processes. *Note: Parks Victoria's BGA risk management plan for Northern Victoria Region that considers the potential risk of environmental water events is	CMA/ GMW Land mgr. GMW

No.	Risk category[1]	Risk description	L[2]	C[3]	Risk rating	Mitigation actions	Lead organisation for action
						currently awaiting final approval. This plan outlines proactive and reactive monitoring and management responsibilities that Parks Victoria commits to as a Local Waterway Manager for BGA. Adequate BGA resourcing is considered as part of this plan. Regional monitoring and advice on BGA status.	GMW
22	BC	Insufficient resources available (including staff, funding for maintenance of roads, regulators etc.) across partner organisations to deliver all planned environmental watering actions, leading to cancellation or interruptions of deliveries.	P	Maj	Medium	Partners notify the CMA and VEWH of resource constraints in advance of deliveries and VEWH convene OAG meetings to consider implications and potential solutions. Continue to actively prioritise actions to match available resources and ensure key actions are delivered. Reallocate tasks and available funds to ensure highest priority watering actions are delivered.	VEWH CMA CMA
23	Env	Insufficient information and knowledge available to inform environmental water deliveries.	U	Mod	Low	Identify important knowledge gaps and secure funding to improve scientific understanding. Consider deferring deliveries until sufficient information is available to mitigate unacceptable risks. Implement adaptive management processes and undertake trials to collect data.	CMA CMA CMA

No.	Risk category[1]	Risk description	L[2]	C[3]	Risk rating	Mitigation actions	Lead organisation for action
24	Legal	Failure to recognise cultural heritage issues at a site targeted for watering may result in necessary permits and approvals not being obtained, leading to prosecution and fines.	P	Mod	Medium	Undertake desktop reviews and site assessments with archaeologists, Traditional Owners and land managers, to identify approval needs and contingency measures. Obtain any necessary formal approvals/permits and implement required actions. Seek necessary resources to undertake approvals and assessments.	CMA CMA
25	Legal	Environmental watering causes harm to identified cultural heritage.	U	Mod	Low	Work with Traditional Owners to ensure that the potential impact of environmental water deliveries on cultural heritage is understood and avoided, minimised and/or acceptable. Consider opportunities for additional resourcing for TO groups to engage in risk assessments.	CMA DEECA/ VEWH
26	Rep	Inability to demonstrate outcomes achieved through environmental watering activities may lead to a loss of public/political support for activities.	P	Maj	Medium	Rationalise and refocus current monitoring programs (e.g. Wetmap) to better identifying outcomes. Seek additional funds to address gaps in monitoring programs and knowledge. Communicate the benefits of environmental watering and monitoring results. Note: It may not be possible/affordable to address all monitoring gaps, so this risk may still be rated as medium after mitigation actions.	DEECA VEWH CMA

No.	Risk category[1]	Risk description	L[2]	C[3]	Risk rating	Mitigation actions	Lead organisation for action
27	Env	Environmental deliveries improve conditions for non-native species (e.g. carp, invasive species, feral horses) leading to adverse environmental impacts. Or pest plants and animals prevent environmental water outcomes being achieved.	L	Mod	Medium	Study/understand life history of species and develop high level management strategies. Develop and implement site specific management strategies aimed at eradication/control of existing populations (e.g. carp management strategy, willow removal program, water-lily spraying program, feral animal programs). Implement pest reduction efforts prior to delivery of water, to ensure increases in populations remain within "tolerable" levels, e.g. consider adjusting timing and magnitude of flows to reduce carp impacts, and check in with fish ecologists. (*Note: This risk is still rated as medium after mitigation actions.*)	DEECA CMA/Land Mgr.
28	Env	Environmental watering actions trigger non-targeted environmental responses (e.g. bird breeding) causing unintended consequences (or lost opportunities) for other environmental values.	L	Mod	Medium	Undertake monitoring and communicate these issues as they arise and apply adaptive management and review of delivery plans. Consider including contingency allowance in delivery plan water volumes to complete breeding events.	CMA CMA
29	Env	Ineffective planning and/or uncoordinated water ordering results in administrative obstacles that prevent watering opportunities.	U	Mod	Low	Enable the full range of watering actions possible in seasonal watering proposals and the seasonal watering plan (as per SWP guidelines).	CMA/VEWH
30	BC	River operators release water for flood mitigation which causes downstream flooding and debits those releases to environmental water accounts.	U	Mod	Low	Resolve appropriate water accounting treatment as part of the development of the Enhanced	VEWH/ DEECA

No.	Risk category[1]	Risk description	L[2]	C[3]	Risk rating	Mitigation actions	Lead organisation for action
		**Note that debits of releases to environmental accounts is specific to Lake Hume and pre-releases from other storages could not be debited to environmental accounts.*				Environmental Water Deliveries SDL Adjustment Measures project (aka Hydrocues project). Refer to MDBA Environmental Water Management Group for development of suitable accounting arrangements.	MDBA
31	Rep	River operators release water for flood mitigation which causes downstream flooding and public perceive the releases are for environmental purposes.	U	Mod	Low	River operators to clearly communicate to customers and the broader community when large releases are for operational purposes.	MDBA/GMW
32	Rep	Sections of the community perceives (incorrectly) that high river flows are due to environmental releases in dry conditions, leading to a loss of support for watering activities.	P	Mod	Medium	Communications to inform the community on the drivers/reasons for high flows in river systems, especially under dry scenarios.	GMW/CMA
33	Rep	Community concern over environmental releases under dry seasonal conditions may lead to a loss of support for environmental watering actions.	U	Mod	Low	Communicate benefits of environmental watering to the community, especially in relation to strategic watering in dry periods. Enhance community understanding of water system operations and entitlement frameworks (water literacy).	CMA VEWH
34	Rep	Under dry conditions, community expectations of the extent of environmental watering that can be achieved are not met, leading to a loss of support for environmental watering actions.	P	Mod	Medium	Communications to inform the community on the limits of environmental water holdings and the extent of actions possible under dry conditions. *Note that public concern in this regard may still be heightened as a result of the 2019 Menindee fish death events.*	CMA

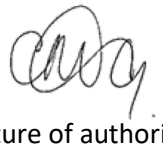
No.	Risk category[1]	Risk description	L[2]	C[3]	Risk rating	Mitigation actions	Lead organisation for action
35	Env	Limited environmental deliveries may reduce opportunities to test ecological responses to environmental flows, impacting on effectiveness of research projects.	U	Min	Low	Review monitoring program and adjust if possible. Reprioritise future flow targets.	CMA
36	People	Environmental releases create rapid or unexpected changes in flow conditions, resulting in injury to river users.	U	Mod	Low	Include consideration of ramp-ups and ramp-down phases in release plans to reduce rapid water level changes. Appropriate notification actions to alert general river users, especially for high use sites and high use periods. Provide information on proposed changes to PV for inclusion in Change of Conditions Section of their website. Implement communications plan about environmental water releases. Undertake notifications to water users with assets potentially at risk due to changing river levels	CMA CMA CMA CMA GMW

Approval and Endorsement

Approval

I, Chris Cumming, the authorised representative of the agency shown below, approve the Seasonal Watering Proposal for the Lower Broken Creek system 2023-24.

SIGNED FOR AND ON BEHALF OF Goulburn Broken Catchment Management Authority



Signature of authorised representative

Name of authorised representative

Chris Cumming (CEO)

Date: 6 April 2023

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