Seasonal Watering Proposal 2022-2023

Broken River System

GOULBURN BROKEN CATCHMENT MANAGEMENT AUTHORITY

Publication details

Published by:

Goulburn Broken Catchment Management Authority,

PO Box 1752, Shepparton 3632

Please cite this document as: GB CMA (2022). Broken River System Seasonal Watering Proposal 2022-2023. Goulburn Broken Catchment Management Authority, Shepparton.

For further information, please contact:

Goulburn Broken Catchment Management Authority

P.O. Box 1752, Shepparton 3632

Phone: (03) 5822 7700

Website: www.gbcma.vic.gov.au

Cover photograph

Upper Broken Creek. Credit Pam Beattie GB CMA.

Executive Summary

The proposal identifies the environmental water requirements of the Broken River and upper Broken Creek in 2022-2023 under a range of Climate scenarios to protect or improve their environmental values and health.

The Broken River has been identified as priority waterway in the Goulburn Broken Waterway Strategy (GB CMA 2014). Both the Broken and the upper Broken Creek are listed as on the Directory of Important Wetlands in Australia (Environment Australia 2001). They also support a diverse and abundant native fish community, provides water for agriculture and support a variety of recreational activities such as fishing, boating, bird watching and camping.

A Broken River Environmental Watering Plan was completed in 2013 and an upper Broken Creek Environmental Flow Study was completed in 2017. These technical studies established ecological objectives and associated flow recommendations which inform environmental water planning, implementation and nonrioting. The Broken River's overarching ecological objective is to maintain the frequency, timing, duration and magnitude of low flows and freshes to improve habitat for native fish, macroinvertebrates and aquatic vegetation. The upper Broken Creek's overarching ecological objectives are:

- Provide permanent habitat for native fish, platypus, macroinvertebrates and other fauna in the upper reach and opportunistic habitat in the lower reaches.
- Protect and enhance the diversity and extent of instream, littoral and riparian vegetation.
- Maintain water quality to support native fish and macroinvertebrates.

To achieve these objectives, environmental water management has focused on maintaining low flow recommendations at critical times of the year and opportunistically delivering small freshes when seasonal conditions allow. Other watering actions have been recommended, but due to the limited volume of environmental water available in the Broken System they cannot be delivered.

La Nina conditions resulted in above average rainfall in the Broken River Catchment in during the 2021-22 season. The above average rainfall saw Lake Nillahcootie fill and spill in August and stay at close to full capacity until mid-November. As a result, the Broken System seasonal allocation reached 100% of high-reliability water shares in September.

Environmental water was used to supplement operations releases and unregulated flows to maintain minimum low flow recommendations in the upper Broken Creek. Operational releases and unregulated flows largely met or exceeded the minimum low flow recommendation in all reaches of the Broken River throughout the season. Therefore, no environmental water releases were required.

All reaches of the Broken River experienced several large natural freshes between July 2021 and February 2022 with peak discharges between 500 ML/day and 8,000 ML/day. Large freshes cannot be delivered using environmental water and are critical to the health and functioning of the River.

In mid and late January, intense rainfall in the Broken River Catchment generated two overbank flow events down the upper Broken Creek. The overbank flows were principally generated by local catchment runoff which entrained large amounts of organic material. The water in the Creek subsequently become hypoxic. To help dilute the black water and improve dissolved oxygen levels, environmental water was used to provide higher baseflows between 20-30 ML/day throughout February. The delivery of priority watering actions next year will be important for the recovery of the Creek.

Consistent with previous proposals, the emphasis of the 2022-23 is to maintain low flows in both the upper Broken Creek and Broken River at critical times of the year and deliver a small fresh in the Broken River in summer or autumn if seasonal conditions allow. The priority watering actions under different climate scenarios in 2022-23 are outlined in the table below.

Flow components	Reach	Season	Flow	Climate scenario			
				Ext. dry	Dry	Average	Wet
				Priority			
Upper Broken Creek							
Low flow	1	spring	10 ML/day	1b	1a	1a	1a
Low flow	1	summer	5 ML/day	1b	1b	1a	1a
Low flow	1	autumn	5 ML/day	1b	1b	1a	1a
Low flow	1	winter	10 ML/day	1b	1b	1a	1a
Water quality management	1	summer/autumn	50-100 ML/day	1b	1b	1b	1b
Broken River							
Low flow	all	spring	15-30 ML/day	1b	1b	1a	1a
Low flow	all	summer	15-30 ML/day	1b	1b	1a	1a
Low flow	all	autumn	15-30 ML/day	1b	1b	1a	1a
Low flow	all	winter	15-30 ML/day	1b	1b	1a	1a
Fresh	all	summer/autumn	400-500 ML/day	NA	1b	1b	1b

1a Critically important actions that should be partly or completely achievable based on estimates of available water resources
1b Critically important actions that are unlikely to be achievable based on estimates of available water resources
2 Actions expected to improve environmental outcomes, but are unlikely to result in negative environmental outcomes if they are not delivered this year

Under all Climate scenarios, the volume of environmental water available is potentially much less than the volume required to deliver the desired priority watering actions. However, opportunities to use inter-valley water transfers in the Broken River to meet priority watering actions will be considered and environmental water holders can back trade water to provide additional water for environmental flows in the Broken River and upper Broken Creek.

The proposal does not take account of competing needs of environmental water use of Moodie Swamp on the upper Broken Creek. However, the delivery of environmental water to Moodie Swamp would help meet upper Broken Creek low flow requirements.

As all the flows proposed are within the channel of the upper Broken Creek and Broken River there is a low risk of adverse outcomes to private assets or the general public from delivering the priority watering actions.

The proposal was developed in consultation with the GB CMA board, the VEWH, the CEWO, GMW, Parks Victoria, Traditional Owners (Yorta Yorta Nations Aboriginal Corporation and Taungurung Land & Waters Council) and the Broken Environmental Water Advisory Group. These groups will also be consulted during the implementation of the proposal.

Contents

List of tables

Table of figures

Glossary and acronyms

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

Low flow - 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) holds and manages the water entitlements purchased through the Restoring the Balance water recovery program

CMA - catchment management authority

Department of Environment, Land, Water and Planning (DELWP) – Victorian government department responsible for protecting the environment, responding to climate change and supporting sustainable population growth

DO - dissolved oxygen level of creek water

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

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

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

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

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 riverbank. Freshes help maintain water quality and serve as 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 water Transfers (IVT) - means bulk transfers of water from the Goulburn water supply system to supply water users in the Murray water supply system

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 (included insects, crustacean, aquatic worms and aquatic snails)

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

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

MDBA – Murray-Darling Basin Authority

Overbank flow - flood flows that overtop the banks and spill onto the floodplain

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

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

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 (characterized 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) - 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 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 and system overview

Environmental entitlements can be delivered to streams and wetlands when needed to protect or enhance their environmental values and health. Environmental entitlements are held in and generally delivered from storages. However, unregulated flows occurring in the system can also contribute to environmental flow deliveries. Environmental entitlements are held by the Victorian Environmental Water Holder (VEWH), the Commonwealth Environmental Water Holder (CEWH), and the Murray Darling Basin Authority (MDBA). In the Broken System, environmental entitlements are only held by the CEWH and the VEWH. Catchment Management Authorities (CMAs) are responsible for determining the environmental water requirements of streams and wetlands, developing and submitting seasonal watering proposals to the VEWH for consideration, and managing the delivery of environmental water.

The VEWH prepares a seasonal watering plan based on each of the CMA's seasonal watering proposals. The plan describes the potential environmental watering activities across Victoria in the coming year. To help facilitate the desired environmental watering activities outlined in the plan, the VEWH negotiates access to environmental water managed by the CEWH and the MDBA. The VEWH then prepares seasonal watering statements that authorises CMAs to undertake the agreed environmental watering activities, including the use of CEWH and MDBA water. As more environmental water becomes available during the season the VEWH may prepare additional seasonal watering statements. Where possible, the VEWH, CEWH and the MDBA seek to coordinate the delivery and management of environmental water to maximise ecological benefits.

Purpose

The purpose of this Broken River System Seasonal Watering Proposal is to:

- identify the environmental water requirements of the Broken River and upper Broken Creek in the coming year under a range of climate scenarios to protect or improve their environmental values and health; and
- inform the development of environmental watering actions in the VEWH's seasonal watering plan.

The proposal is informed by scientific studies and reports that identify the flow regimes required to meet the ecological objectives of the Broken River System. This proposal was prepared in consultation with key stakeholders and partners and was approved by the CEO of the GB CMA.

System overview

The Broken River and the upper Broken Creek are connected waterways in the Broken River catchment.

Broken River

The Broken River rises in the Wellington-Tolmie highlands of central Victoria and flows in a westerly direction to Lake Nillahcootie. The river then flows north to Benalla and then west again before it discharges to the Goulburn River near Shepparton (Figure 1).

The Broken River has the characteristics of a foothills stream with relatively steep, confined sections immediately below Lake Nillahcootie. The river then takes on the characteristics of a lowland river with a more extensive floodplain downstream of Swanpool until its confluence with the Goulburn River at Shepparton. The main tributaries of the Broken River include Hollands Creek, Ryans Creek, and Lima East Creek (formerly Moonee's Creek). Much of the study area has been cleared for agriculture, including dryland (livestock grazing and cereal cropping) and irrigated agriculture (dairy, fruit, livestock).

The Broken River has been identified as priority waterway in the Goulburn Broken Waterway Strategy (GB CMA 2014) and is listed as on the Directory of Important Wetlands in Australia (Environment Australia 2001). The River supports a diverse and abundant native fish community. Fish species supported include the threatened Murray cod (*Macullachella peelii*), Macquarie perch (*Macquaria*

australasica), Golden perch (*Macquaria ambigua*), Silver perch (*Bidyanus bidyanus*), Australian smelt (*Retropinna semoni*), River blackfish (*Gadopsis marmoratus*), Mountain galaxias (*Galaxias olidus*) and Murray-Darling rainbowfish (*Melanotaenis fluviatilis*). The river is also thought to support a large platypus (*Ornithorhynchus anatinus*) population (Serena and Williams, 2010).

The main channel of the Broken river supports beds of submerged and emergent aquatic vegetation such as Eelgrass (*Vallisneria australis*), Common reed (*Phragmites australis*) and Water ribbons (*Triglochin procera*). This sets the Broken River apart from other major rivers in the regions, such as the Goulburn River, where such stands of aquatic vegetation are relatively scarce. The River and associated floodplain and wetland habitats also contain important cultural heritage sites and support a variety of recreational activities such as fishing, boating, birdwatching and bushwalking.

Mean annual streamflow for the Broken Basin is approximately 308 GL (DSE 2009). Streamflow is variable, both across years and across seasons. Lake Nillahcootie (capacity 40,000 ML) stores water during the winter/spring for release in spring/summer/autumn to supply predominantly irrigation demands along the river downstream to Shepparton and reach 1 of the upper Broken Creek. The tributaries downstream of Lake Nillahcootie also make significant contributions to stream flows.

Lake Nillahcootie fills in most years, as the storage capacity is approximately half of the mean annual flow of that section of the Broken River. It is regularly drawn down to less than 30% capacity by the end of the annual irrigation season. Water is released to meet downstream demand and minimum flow requirements specified under the Bulk Entitlement for the Broken River system. Releases from the dam may be less than 30 ML/d as tributary inflows immediately below the dam (e.g., Back Creek) can supply much of the flow required to meet the bulk entitlement minimum flow requirements. There is a small flow balancing storage associated with Broken Weir, upstream of Benalla.

The operation of Lake Nillahcootie has modified the river's natural flow pattern causing winter-spring flows to be lower and summer-autumn low flows to be higher to meet irrigation demands. These impacts are most pronounced downstream of Lake Nillahcootie to Hollands Creek. However, downstream of Hollands Creek to the Goulburn River it still retains a largely natural flow pattern in average and wet years (including both high and low flows).

Upper Broken Creek

The Broken Creek is a distributary stream of the Broken River and flows north from the Broken River at Caseys Weir to the Boosey Creek confluence near Katamatite Township. At this point the Broken Creek follows in a westerly direction until it meets the Murray River at Barmah Forest. For this document the upper Broken Creek is defined as the stretch from Caseys Weir to Katamatite Township. This stretch is approximately 89 kilometres long.

The upper Broken Creek has significant environmental values. It supports an array of aquatic fauna species including platypus, Common Long-necked turtle and the threatened Murray cod, golden perch, silver perch and Murray-Darling rainbowfish. The surrounding floodplain and wetland habitats support box dominated grassy woodland communities and numerous threatened species including Brolga, Australasian Bittern, Buloke and Rigid Water Milfoil. The Creek and associated floodplain and wetland habitats also contain important cultural sites and support a variety of recreational activities such as fishing, birdwatching and game hunting. The upper Broken Creek is listed on the Directory of Important Wetlands in Australia (Environment Australia 2001) and stretches have been set aside as a Natural Features Reserve.

The upper Broken Creek has been regulated for over 100 years. Prior to 2007 water was diverted from the Broken River at Caseys Weir to the upper Broken Creek from where it was distributed via natural waterways and a system of weirs and channels to supply stock, domestic and irrigation water to landholders. This transformed the upper Broken Creek from an intermittent and seasonally variable stream into a near perennial stream.

As part of a Murray-Darling Basin water savings initiative, a pipeline was constructed and commissioned in 2007 to deliver stock and domestic water to landholders along the upper Broken Creek (known as the Tungamah Pipeline Scheme). This was expected to reinstate a more natural flow regime to the upper Broken Creek. However, due to the influence of ongoing irrigation demand in the upper Broken Creek, changes to the flow regime have not been as dramatic as first expected. Today the Creek from Caseys Weir to Waggarandall Weir is largely perennial with low flows maintained throughout summer and autumn to supply water for irrigation. Some of this water passes downstream to Reillys Weir providing a low flow throughout most of summer and autumn. Downstream of Reillys Weir the Creek follows a more natural summer and autumn flow pattern with regular cease to flow periods. This contraction of permanent aquatic habitat has impacted the distribution an abundance of aquatic and terrestrial biota, particularly large flow dependent native fish species which are now largely restricted to areas above Waggarandall Weir. Winter flows along the length of the upper Broken Creek are variable and dominated by catchment runoff. It also receives flood flows from the Broken River. However, levees and a road obstruct the flow path reducing their natural frequently.

Priority reaches and measuring points

Flow recommendations were developed for the Broken River in 2013 and the upper Broken Creek in 2007 and again in 2017. To facilitate this process, they were divided into reaches with similar channel morphology, flow regime and ecological values (Figure 1).

The Broken River reaches are:

1. Downstream of Lake Nillahcootie to Hollands Creek (38 km);
2. Hollands Creek to Caseys Weir (14 km); and
3. Caseys Weir to the Goulburn River (69 km).

The upper Broken Creek reaches are:

1. Caseys Weir to Waggarandall Weir (40 km);
2. Waggarandall Weir to Reillys Weir (24 km); and
3. Reillys Weir to Katamatite (25 km).

While all reaches of both the Broken River and the upper Broken Creek are important, the highest priorities are reach 3 of the Broken River and reach 1 of the upper Broken Creek, particularly during drought and dry years, as they support the most diverse and abundant native fish communities. Reach 1 of the upper Broken Creek also supports a large permanent platypus population, while reaches 2 and 3 are thought to support small transient populations. All reaches of the Broken River are likely to support large permanent platypus populations.

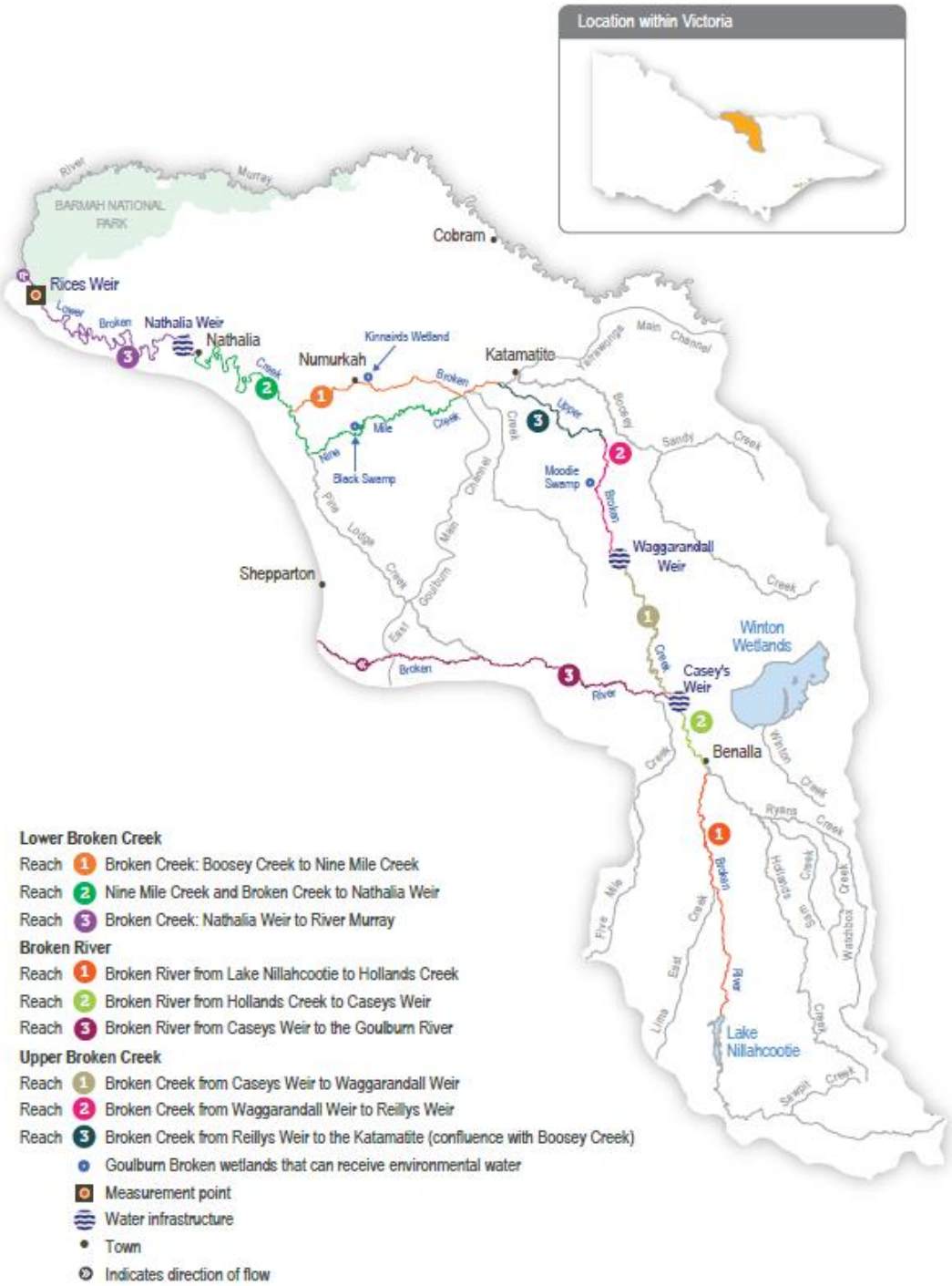
The natural flow pattern of reach 1 in the Broken River has been modified the most by regulation. Providing environmental water to this reach to increase flow variability is important when possible. This will also benefit the downstream reaches.

The key environmental flow measurement points for the Broken River are:

- Back Creek Junction in reach 1;
- Caseys Weir in reach 2; and
- Gowangardie Weir in reach 3.

The key environmental flow measurement point for the upper Broken Creek is Waggarandall Weir in reach 1.

Figure 1: Broken River Basin (prepared by the VEWH)



Water sources

Water available for use in the Broken River System (Table 1) includes:

- minimum passing flows established in the Bulk Entitlement (Broken System – Goulburn-Murray Water) Conversion Order 2004 and subsequent amendments;
- environmental entitlements held by the CEWH and VEWH; and
- unregulated flows.

Table 1: Environmental water available for use in the Broken River System

Environmental water	Responsible agency	Description	Conditions
Bulk Entitlement (Broken System – Goulburn-Murray Water) Conversion Order 2004			
Minimum flow	GMW	Minimum flow of 30 ML/d or natural (whichever is lower) from June to November in the Broken River at Back Creek Junction.	
Minimum flow	GMW	Minimum flow of 22 ML/d or natural (whichever is lower) from December to May in the Broken River at Broken Weir.	
Minimum flow	GMW	Minimum flow of 25 ML/d or natural (whichever is lower) from December to May in the Broken River at Gowangardie Weir.	
Environmental water entitlements			
Commonwealth Environmental Water Holdings	CEWH	534 ML Broken high reliability water share and 4 ML Broken low reliability water share.	Water use is subject to agreement with the CEWH.
Victorian Environmental Water Holdings	VEWH	90 ML Broken high reliability water share and 18.9 ML Broken low reliability water share.	

Allocation can be traded from the Broken System to the lower Goulburn River and downstream between July 1 and 31 March and if the Broken Inter-Valley Trade account does not exceed 1500 ML. The delivery of trade commitments is expected to occur primarily between December and March and can be delivered in a manner to help meet environmental flow objectives. In 2021-2022 (up to March) a total of 4,324 ML was traded out of the system. Trade also creates an opportunity to trade allocation into the Broken system. Environmental water holders can use this trade opportunity to provide additional water for environmental flows in the Broken system by transferring allocation in from another connected trading zone. In 2021-2022 1,700 ML of water was traded into the Broken system by environmental water holders to provide additional water resources for priority watering actions.

As part of an agreed Watering Schedule between the VEWH and the CEWH the environmental water entitlement can be used in the upper Broken Creek, Moodie Swamp (see Broken Wetlands Seasonal Watering Proposal 2022-23) and Broken River. This also allows the VEWH and or CEWO to transfer in volumes when required to meet environmental demand in these waterways.

The GB CMA in agreement with GMW can also reduce Broken River passing flows to bank water to help deliver Broken River and upper Broken Creek priority watering actions.

Engagement

Key community and stakeholder groups have been engaged during the development of this proposal. These include:

- The agencies directly involved in delivering the proposed priority flow recommendations including Goulburn-Murray Water (GMW), the VEWH and the CEWH.
- The agencies directly involved in the management of public land covered by the proposal (Parks Victoria and DELWP).
- Traditional Owners (Yorta Yorta Nations Aboriginal Corporation and Taungurung Land & Waters Council) who have rights and interests in the land and water covered by the proposal.
- Individuals or groups potentially affected by or interested in environmental flows and or the health of the Broken River and upper Broken Creek. This includes water users along the waterways (GMW diversion license holders), campers, fishers, local government and environment groups and the general public.

Ongoing engagement with these groups primarily occurs through three mechanisms – the Broken Environmental Water Advisory Group (EWAG), the Goulburn Broken Operational Advisory Group (GBOAG) and direct engagement via emails, telephone and face to face meetings.

GMW is the key water delivery agency. When the final proposal for 2022-2023 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 and email) directly with the water resource management group in GMW to understand unregulated flows, GMW planned consumptive use releases, and to organise environmental flow releases.

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 and email) will report on deployment of water under the plan as the year unfolds.

The CEWO also undertakes annual planning and publishes plans on the CEWO website. Planning by the GBCMA, CEWO and VEWH is undertaken in close cooperation with each other to create a shared understanding of the watering priorities and ecological outcomes to be achieved.

A Goulburn and Broken Operational Advisory Group was formally established by the Victorian Environmental Water Holder (VEWH) in 2016 and is comprised of representatives from the VEWH, Goulburn-Murray Water, CEWO, MDBA and GBCMA. Representatives from Yorta Yorta Nations Aboriginal Corporation and Taungurung Land & Waters Council were invited to join the group in 2022. This group aims to provide a regular and coordinated forum to discuss the environmental water resource management planning and delivery in the Goulburn and Broken River systems and discuss how this impacts system scale coordination.

To assist with the environmental water management program, the GB CMA established the Broken Environmental Water Advisory Group to provide advice on environmental water planning (including seasonal watering proposals and water management plans) and on environmental health trends occurring in the rivers, creeks and wetlands. The focus of 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 was established in April 2012 and comprises community members, Traditional Owners (Taungurung Land & Waters Council and Yorta Yorta Nations Aboriginal Corporation) and representatives from key agency partners (VEWH, CEWH, PV and GMW).

Traditional Owners are also directly consulted during the development and implementation of the Broken River System seasonal watering proposal through regular meetings with GB CMA staff.

The general public and individuals or groups potentially affected by or interested in environmental flows and or the health of the Broken River and upper Broken Creek are primarily engaged through media releases and partner communication platforms. The communication objective for this audience is to provide information about decisions to deliver environmental water and the expected ecological outcomes. A secondary objective is to build public understanding of the change from past flow regimes to a future one managed to achieve improved river health.

Error! Reference source not found. outlines the communication process the GB CMA has undertaken d uring the development of this seasonal watering proposal. This is described in further detail in the Goulburn Broken Environmental Water Communication Action Plan, which is reviewed and refined throughout the year.

Table 2: Engagement undertaken

Who		IAP2 level of engagement	Engagement methods	Engagement purpose
Government agencies	GMW VEWH CEWH Parks Victoria	Collaborate	Broken EWAG meeting in February 2022 Direct engagement	Seek input to development of the proposal. Understand any delivery constraints or issues and plan for environmental water delivery in 2022-23
Traditional Owners	Yorta Yorta Nation Aboriginal Corporation	Involve	Direct engagement meeting in March 2022	Identify Aboriginal values and uses of the creeks Seek feedback on environmental water priorities for 2022-23
	Taungurung Land and Waters Council	Involve	Broken EWAG meeting in February 2022 Direct engagement meeting in March 2022	
Recreational Users	EWAG members	Involve	Broken EWAG meeting in February 2022	Confirm recreational and social uses of the creeks Seek feedback on environmental water priorities for 2022-23
Environment Groups	Goulburn Valley Environment Group	Involve	Broken EWAG meeting in February 2022	Seek feedback on environmental water priorities for 2022-23
Landholders	EWAG members	Involve	Broken EWAG meeting in February 2022	Gather observations on creek health and trends Seek feedback on environmental water priorities for 2022-23

Aboriginal cultural values and uses of waterways

Traditional Owners value implementing more natural flow regimes 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 upper Broken Creek and the Broken River downstream of Benalla under the Aboriginal Heritage Act (2006). Taungurung Land and Waters Council is the Registered Aboriginal Party for the Broken River upstream of Benalla under the Aboriginal Heritage Act (2006).

Yorta Yorta Nation Aboriginal Corporation provided the following statement about the cultural values of the Broken River and upper Broken Creek in 2021:

'*The Broken River (and upper 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 river also has significant stands of old growth river red gum containing important habitat and exhibiting scars made from carving out canoes and coolamons*.'

In consultation with the Taungurung Land and Waters Council specific cultural values were not identified for the Broken River and the upper Broken Creek for 2022-23. However, the environmental and ecological objectives of the seasonal watering proposal align with their Land and Water Management Plan. This supports the health of cultural values and landscapes including intangible cultural heritage and valued species, traditional food and medicine plants. Taungurung Land and Waters Council are planning to assess the Broken River's cultural values through an Aboriginal Waterway Assessment. The GB CMA will support this activity and the outcomes will help inform future Broken River environmental water planning, delivery and monitoring.

Involvement of Yorta Yorta Nation Aboriginal Corporation and the Taungurung Land and Waters Council in environmental water planning, delivery and monitoring where possible, increases their literacy and understanding of conservation and water management within their Country.

Both Yorta Yorta Nation Aboriginal Corporation and Taungurung Land and Waters Council have been directly engaged during the development of this plan (see table 2) and have provided letters of support.

Social, recreational and economic values and uses of waterways

The Broken River and upper Broken Creek have narrow riparian zones with residential and farming properties adjoining or overlooking them. The Broken River also runs through the centre of the rural community of Benalla. Consequently, the waterways have high aesthetic and amenity values and the communities have a direct connection with them. In a dry environment, water and green spaces are important for wellbeing and to the mental health of the community.

The waterways are also important recreational areas in terms of fishing, canoeing, kayaking and passive recreation. Delivery of water for the environment has helped support these activities including providing low flows that maintain native fish habitat.

The Broken River and upper Broken Creek is the source of consumptive water (irrigation, stock and domestic) for many adjoining landholders. Lower sections of the Broken River and the upper Broken Creek are prone to poor water quality. Delivery of low flows improves water quality for local diverters and improves the efficiency of consumptive water deliveries.

The expected shared benefits from delivery of water for the environment in the Broken River and the upper Broken Creek in 2022-23 are outlined below. These are based on the shared benefits that were realised in previous years and the outcomes of community and stakeholder engagement during development of this seasonal watering proposal.]

Table 3: Shared benefit considerations for the Broken River System

Shared benefit	Beneficiary	How have these benefits been considered?
Mental health and wellbeing	Local community	Providing a green space and water in a dry landscape over summer
Recreation	Benalla Rural City Council, local community, recreational groups, fishers, hunters and bird watchers	• Environmental water provides attractive landscapes for camping, bushwalking, picnicking, community events and swimming by improving water quality and flow • Environmental water helps to maintain and improve native fish populations which supports recreational fishing and associated industries • Environmental water helps to maintain and improve water bird habitat which supports duck hunting • Environmental water helps to maintain and improve water and terrestrial bird habitats which supports bird watching activities
Agriculture	Farmers	• Environmental water helps to maintain and improve water and terrestrial bird populations which help to control agricultural pests (invertebrates) • Environmental water improves the efficiency of consumptive water deliveries • Environmental water improves the quality of irrigation, stock and domestic water

Environmental Objectives and Flow Recommendations

This section outlines the environmental flow objectives established for the Broken River and the upper Broken Creek, and the corresponding flow recommendations including the volume, timing, duration and frequency of flow components.

Broken River objectives and recommendations

An environmental flows study for the Broken River was completed in 2001 (Cottingham et al 2001) and updated in the Environmental Watering Plan completed in 2013 (Cottingham et al 2013b). The Environmental Watering Plan developed objectives and flow recommendations for the management of the Broken River's key ecological values. To facilitate this the Broken River was divided into the following three reaches:

1. Broken River from Lake Nillahcootie to Holland's Creek (38 km);
2. Broken River from Holland's Creek to Caseys Weir (14 km); and
3. Broken River from Caseys Weir to the Goulburn River (69 km).

Given the small volume or environmental water available and the opportunity to utilise Inter-valley water transfers between December and March, the focus of this proposal is on maintaining minimum base flows and increasing flow variability in all reaches. The relevant objectives, flow recommendations and ecological values are listed in Table 4 on the following page. The complete list of objectives and flow recommendations for the management of the Broken River's key ecological values are outlined in Appendix 1.

Upper Broken Creek objectives and recommendations

An environmental flows study for the Broken Creek was completed in 2007 (SKM 2007) during the construction of the Tungamah Pipeline Scheme. Once completed the scheme was expected to lead to a more intermittent flow regime in the upper Broken Creek. However, ongoing irrigation diversions along the upper Broken Creek to supply irrigators between Caseys Weir and Waggarandall Weir means a more perennial flow regime persists. This permanent flow means that some sections of the upper Broken Creek can support environmental values that were not considered in the 2007 study and some of the environmental flow objectives and recommendations established in the 2007 study are no longer valid. Consequently, a new flow study was completed in 2017 that developed objectives and flow recommendations that better reflected the ecological values and flow regime of the upper Broken Creek. To facilitate this the upper Broken Creek was divided into the following three reaches (the same reaches identified in the 2007 study):

1. Caseys Weir to Waggarandall Weir (40 km);
2. Waggarandall Weir to Reillys Weir (24 km); and
3. Reillys Weir to Katamatite (25 km).

Given the delivery constraints in reach 2 and the small volume of environmental water available, the focus of this proposal is on maintaining minimum base flows (flow compliance point is Waggarandall Weir). The relevant objectives, flow recommendations and ecological values are listed in Table 5 on the following page. The complete list of objectives and flow recommendations for the management of the upper Broken Creek's key ecological values are outlined in Appendix 2.

Table 4: Environmental objectives and flow components for the Broken River

Flow component id no.	Flow component	Ecological value	Ecological objectives	Season	Frequency	Duration	Flow (ml/day)			Comment
							Reach 1	Reach 2	Reach 3	
1	Low flow	Riffles, slackwater, pools, aquatic vegetation, native fish and macroinvertebrates	Maintain hydraulic habitat diversity (riffles, slackwater and pools) which supports native fish, macrophytes and macroinvertebrates.	Spring Summer Autumn Winter	Annual	Continuous	30-100 or natural (min. of 15)	30-100 or natural (min. of 15)	30-100 or natural (min. of 15)	Consistent with the 2013 EWMP
2	Fresh	In-channel habitat diversity and native fish	Turn over bed sediments and scour around large wood. Provide flow cues to stimulate native fish breeding and migration movements.	Summer Autumn	1 in summer or autumn	See notes in columns to the right	400 (2 days in dry years 5 days in average years 8 days in wet years)	400 (3 days in dry years 5 days in average and wet years)	400 (3 days in dry years 5 days in average and wet years)	Consistent with the 2013 EWMP
3	Fresh	Biofilms, macrophytes and native fish	Promote biofilm productivity. Maintain macrophyte habitat. Provide habitat for native fish passage. Provide flow cues to stimulate native fish breeding and migration movements.	Summer Autumn	1 in summer or autumn	2 days in dry years 5 days in average years 8 days in wet years	500			Consistent with the 2013 EWMP

Table 5: Environmental objectives and flow components for the Upper Broken Creek

Flow component id no.	Flow component	Ecological value	Ecological objectives	Season	Frequency	Duration	Flow (ml/day)			Comment
							Reach 1	Reach 2	Reach 3	
1	Low flow	Native fish, platypus and macroinvertebrates	Maintain conditions for self-sustaining populations of native fish. Maintain self-sustaining populations of macroinvertebrates. Maintain the platypus population and support successful breeding and juvenile dispersal.	Summer Autumn	All season	All season	5 (dry) 10 (av.) 10 (wet)	NA	NA	Consistent with the 2017 Flows Study
2	Low flow	Native fish, platypus and macroinvertebrates	Maintain self-sustaining populations of native fish. Maintain self-sustaining populations of macroinvertebrates. Maintain the platypus population and support successful breeding and juvenile dispersal.	Winter Spring	All season	All season	10 (dry) 15 (av.) 20 (wet)	NA	NA	Consistent with the 2017 Flows Study

In addition to the above flow recommendations, environmental water may be needed to manage poor water quality in the upper Broken Creek. This could be the result of floods, low and cease to flow events, intense rainfall and fire. Flows of 50-100 ML/d (at the top of reach 1) for 10 days may be required to respond to these events.

Seasonal Review

La Nina conditions resulted in above average rainfall in the Broken River Catchment over the last 12 months and maximum daily temperatures were slightly below average. The above average rainfall saw Lake Nillahcootie fill and spill in August and stay at close to full capacity until mid-November. As a result, the Broken System seasonal allocation reached 100% of high-reliability water shares in September.

Broken River

In autumn (March 2021 to May 2021) the average daily flow was 58 ML/day in reach 1, 50 ML/day in reach 2 and 55 ML/day in reach 3. During this period the average daily flow was less than 30 ML/day for 18 days in reach 1, 3 days in reach 2 and 1 day in reach 3. The average daily flow did not drop below 15 ML/day in all 3 reaches during this time.

In winter (June 2021 to August 2021) the average daily flow was 108 ML/day in reach 1, 650 ML/day in reach 2 and 680 ML/day in reach 3. During this period the average daily flow in reach 1 was less than 30 ML/day for 22 days and did not drop below 15 ML/day on any single day. Flow did not go below 15 or 30 ML/day in reaches 2 and 3 on any single day.

In spring (September 2021 to November 2021) the average daily flow was 316 ML/day in reach 1, 745 ML/day in reach 2 and 790 ML/day in reach 3. During this period the average daily flow did not go below 15 or 30 ML/day on any single day.

In summer (December 2021 to February 2022) the average daily flow was 65 ML/day in reach 1, 189 ML/day in reach 2 and 242 ML/day in reach 3. During this period the average daily flow was less than 30 ML/day for 5 days in reach 1 and 1 day in reach 3. The average daily flow was less than 15 ML/day for 2 days in reach 1 and 1 day in reach 3.

Operational releases and unregulated flows largely met or exceeded the minimum low flow recommendation in all reaches throughout the season. Therefore, no environmental water releases were required. Low flows maintain aquatic habitat for native fish, macrophytes, platypus and macroinvertebrates.

All reaches of the river experienced several large natural freshes between July 2021 and February 2022 with peak discharges between 500 ML/day and 8,000 ML/day. These high flows would have:

- entrained organic material from benches and bars supporting food webs;
- refreshed biofilms and filamentous algae, which are an important food source for macroinvertebrates and fish;
- increased native fish and macroinvertebrate habitat;
- stimulated native fish movement and breeding;
- maintained in-channel habitat diversity; and
- maintained riparian and in-channel vegetation condition.

However, the fresh events in January and February may have temporarily disturbed slow flowing habitats and the abundance of invertebrates such as shrimp. This could impact native fish recruitment and survival, particularly summer spawners such as Murray-Darling rainbowfish.

Annual native fish population monitoring was undertaken in Reaches 1 and 3 in March by ARI staff. Preliminary results indicate Reach 1 supports a diverse native fish community. Native species recorded included Murray cod, Golden perch, River blackfish, Murray-Darling rainbowfish, Southern Pygmy Perch and the nationally endangered Macquarie Perch. This was the first time Reach 1 has been surveyed and the data will provide useful baseline information. In Reach 3 good numbers of Murray cod were recorded including young-of-year (no recruitment was detected last year). Small-bodied species such as Murray-Darling rainbowfish, Australian smelt and Carp gudgeon were evenly distributed but in relatively low abundance. One Silver perch was recorded downstream of Gowangardie Weir (none were recorded last year) (ARI 2022).

The results also highlight the need to maintain the minimum low flow recommendation and provide a late summer/autumn fresh when possible

Figure 3a and 3b below shows the average daily flow (ML/day) at Back Creek Junction, Caseys Weir and Gowangardie Weir on the Broken River from March 2021 to March 2022. It also shows Holland Creek flow, which influences Broken River flows in reaches 2 and 3.

Figure 2: Native fish captured during Broken River annual fish population survey in March 2022 (Top - Silver perch: middle – juvenile Murray cod: bottom - Murray-Darling rainbowfish). Photo credits ARI.

Figure 3a: Broken River flows from March 2021 to March 2022

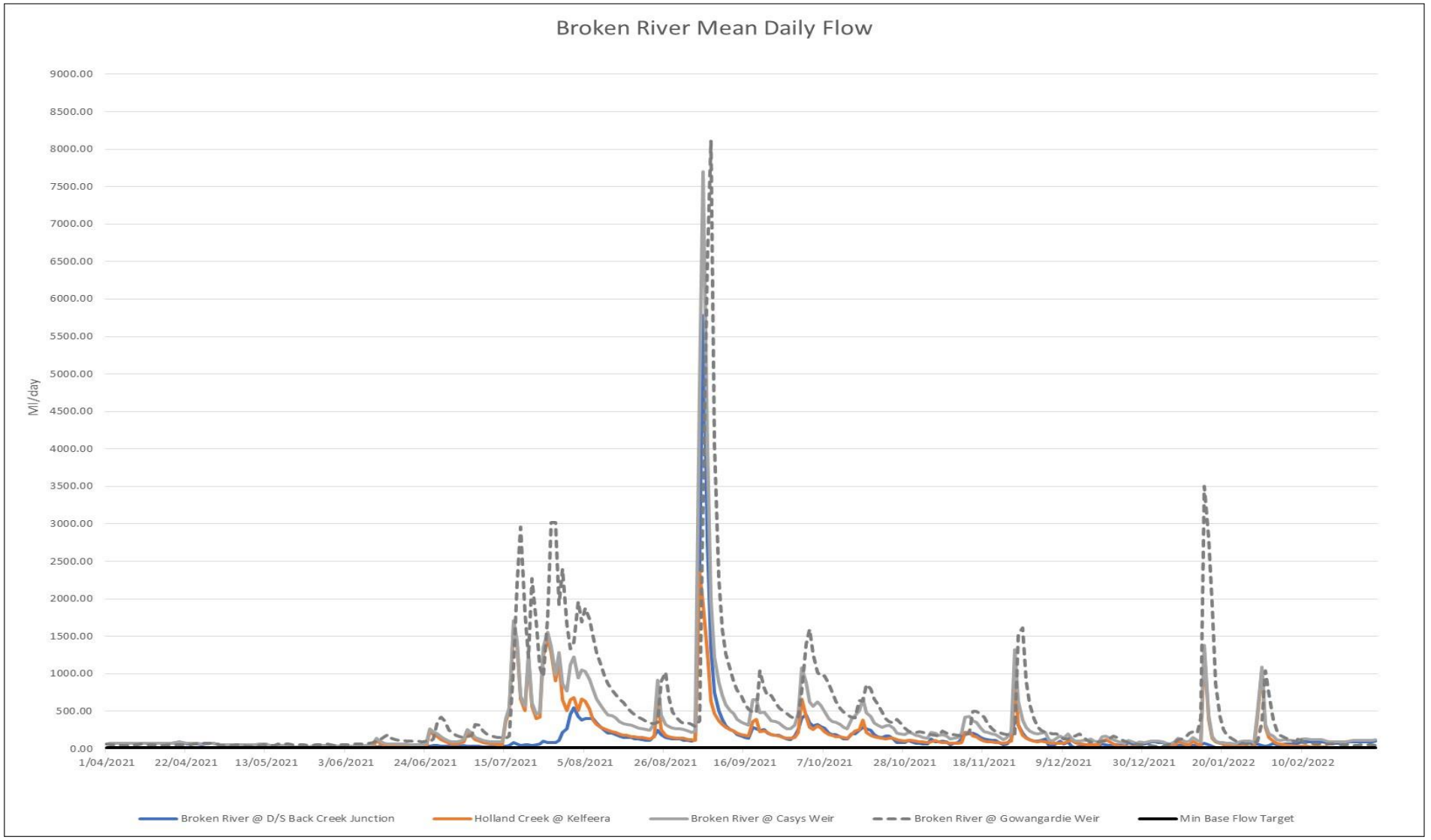
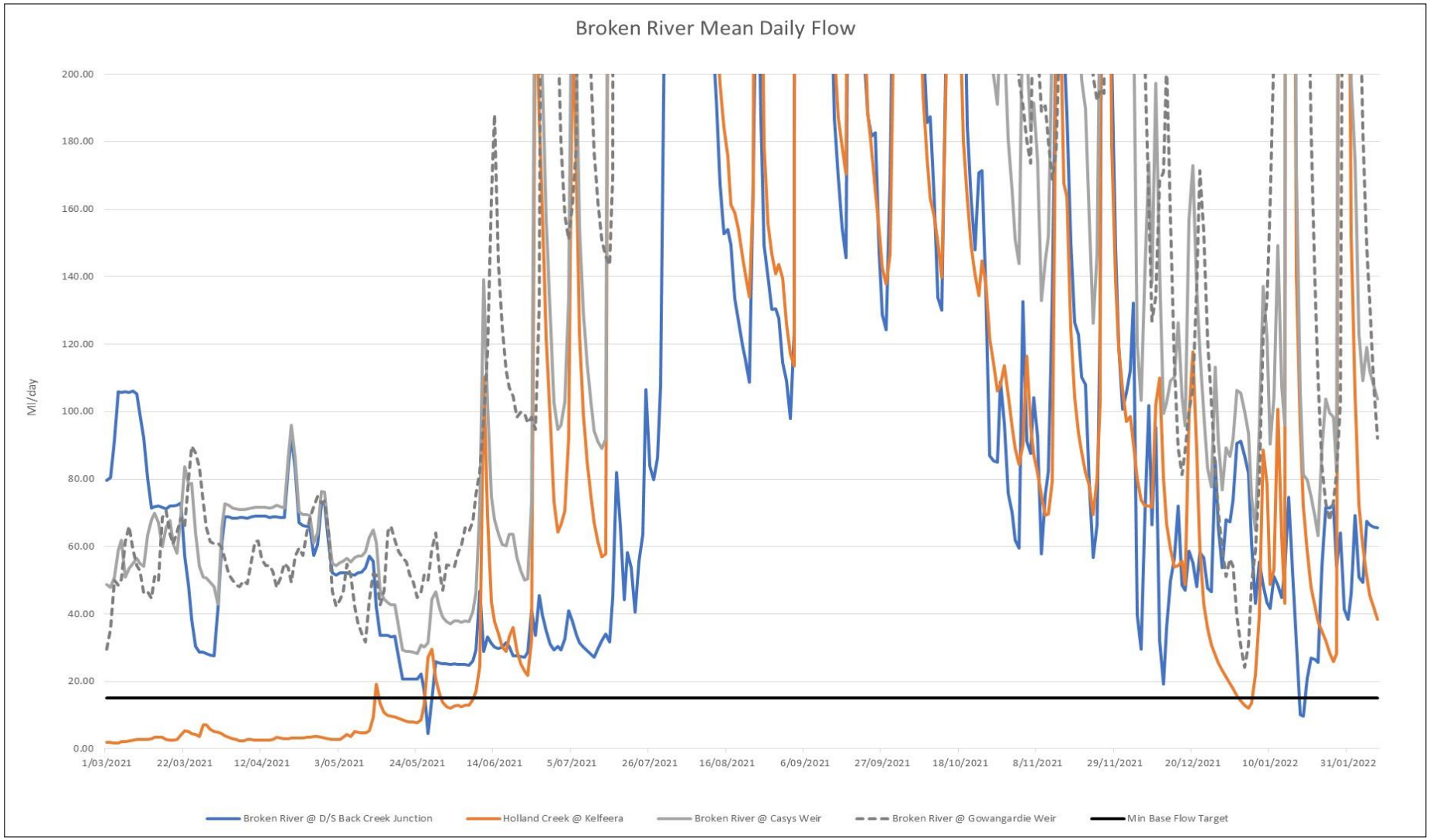


Figure 3b: Broken River flows from March 2020 to March 2021



Upper Broken Creek

In autumn (March 2021 to May 2021), approximately 418 ML of environmental water was used to maintain the minimum low flow recommendation of 5 ML/day. During this time, the average daily flow at Waggarandall Weir was approximately 4.9 ML/day and the average daily flow was less than 5 ML/day for 45 days (approximately 48% of the time).

In winter (June 2021 to August 2021), no environmental water was available to maintain the minimum low flow recommendation of 10 ML/day. During this time, the average daily flow at Waggarandall Weir was approximately 4.6 ML/day and the average daily flow was less than 10 ML/day for 86 days (approximately 93% of the time).

In spring (September 2021 to November 2021), approximately 856 ML of environmental water was delivered to Moodie Swamp (downstream of Waggarandall Weir). This water in transit to Moodie Swamp was also used to maintain the minimum low flow recommendation of 10 ML/day. During this time, the average daily flow at Waggarandall Weir was approximately 13 ML/day and the average daily flow was less than 10 ML/day for 45 days (approximately 48% of the time).

In summer (December 2021 to February 2022), approximately 668 ML of environmental water was used to maintain the minimum low flow recommendation of 5 ML/day. Some of this water was in transit to Moodie Swamp which finished receiving environmental water on the 23 December. In mid and late January, intense rainfall in the Broken River Catchment generated two overbank flow events down the upper Broken Creek. The overbank flow events had peak discharges of approximately 180 ML/day at Waggarandall Weir on the 18 January and the 2 February. The overbank flows were principally generated by local catchment runoff which entrained large amounts of organic material. The water in the Creek subsequently become hypoxic (Figure 4). To help dilute the black water and improve dissolved oxygen levels, environmental water was used to provide higher baseflows between 20-30 ML/day (measured at Caseys Weir at the top of reach 1) throughout February. This did result in some improvement in dissolved oxygen levels, but they did not consistently return to normal levels (Figure 5). The return of normal dissolved oxygen levels may take some time due to the high organic load in the Creek. Approximately 50 fish died at Flynns Weir in late January in response to low dissolved oxygen levels. The fish were predominately European carp and included a small number of Murray cod. No other impacts on aquatic fauna were identified, however the low dissolved oxygen levels may have impacted macroinvertebrates which are an important food source for native fish, platypus and waterbirds. The delivery of priority watering actions next year will be important for the recovery of the Creek.

In summer the average daily flow at Waggarandall Weir was approximately 9 ML/day. This was a result of the two overbank flow events and a higher baseflow during February in response to the blackwater event. Despite this, the average daily flow was less than 5 ML/day for 27 days (approximately 30% of the time).

Without the delivery of environmental water to supplement operational releases and unregulated flows the average daily flow at Waggarandall Weir would have been significantly lower. This would have increased the risk of low dissolved oxygen levels and reduced available habitat for native fish, platypus and macroinvertebrates. Environmental water will be delivered through autumn and winter 2022 to maintain minimum low flow recommendations.

A local landholder sighted two platypus and a Rakali on the upper Broken Creek downstream of Waggarandall Weir in October 2021. This indicates that environmental water deliveries in spring provide suitable habitat for both Platypus and Rakali downstream of Waggarandall Weir. Brolga and variety of other waterbirds were also recorded along the upper Broken Creek by GB CMA staff in spring and summer feeding and roosting. The upper Broken Creek may provide important waterbird habitat in the region as wetland habitat has been significantly impacted by land uses changes and river regulation.

In addition to the two overbank flow events in summer, reach 1 of the upper Broken Creek experienced one small fresh in winter. Freshes are important to the ecology of the upper Broken Creek as they:

- inundate benches and banks providing soil moisture for littoral and riparian vegetation;
- provide increased habitat and passage for native fish and platypus; and
- help maintain water quality.

Figure 4: Blackwater at Waggarandall Weir January 2022

Figure 5: Upper Broken Creek dissolved oxygen levels

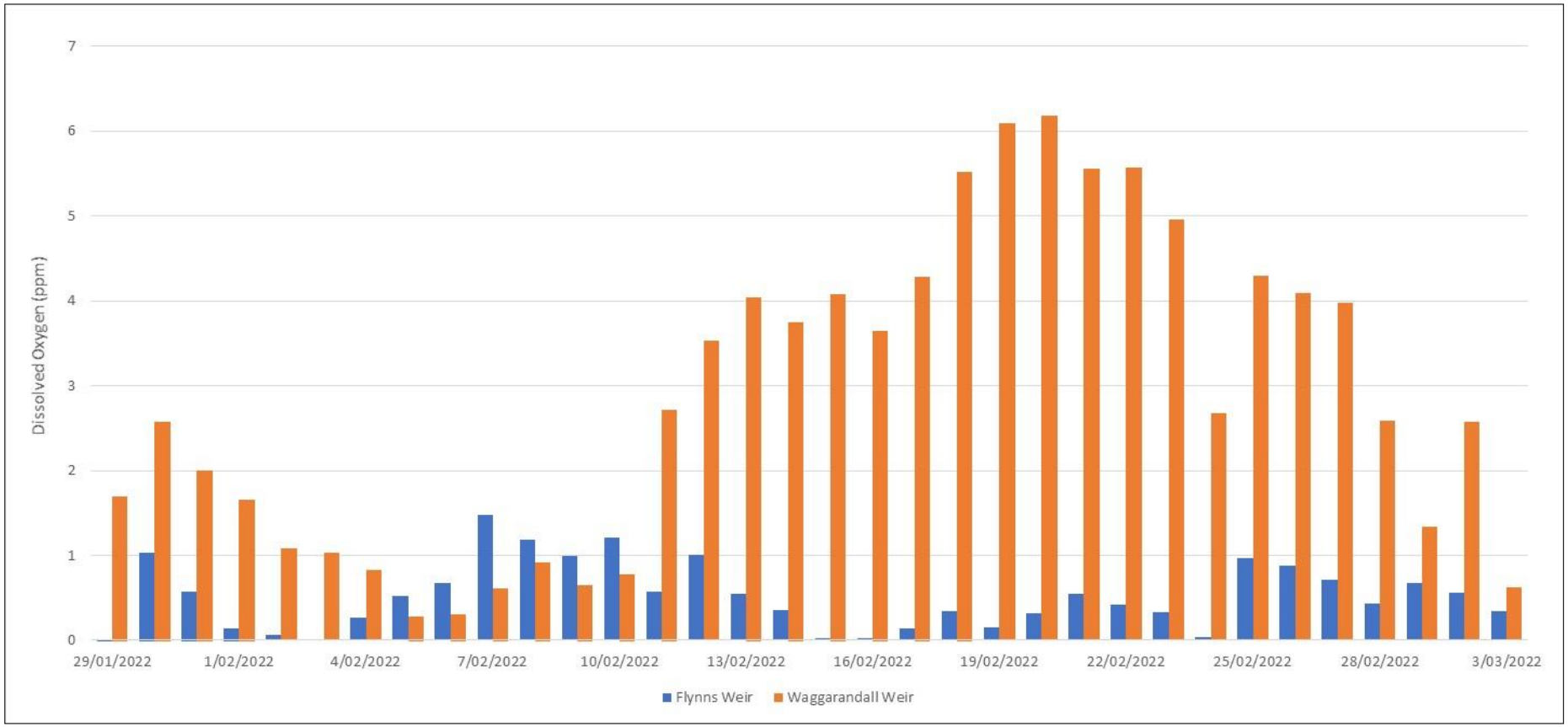
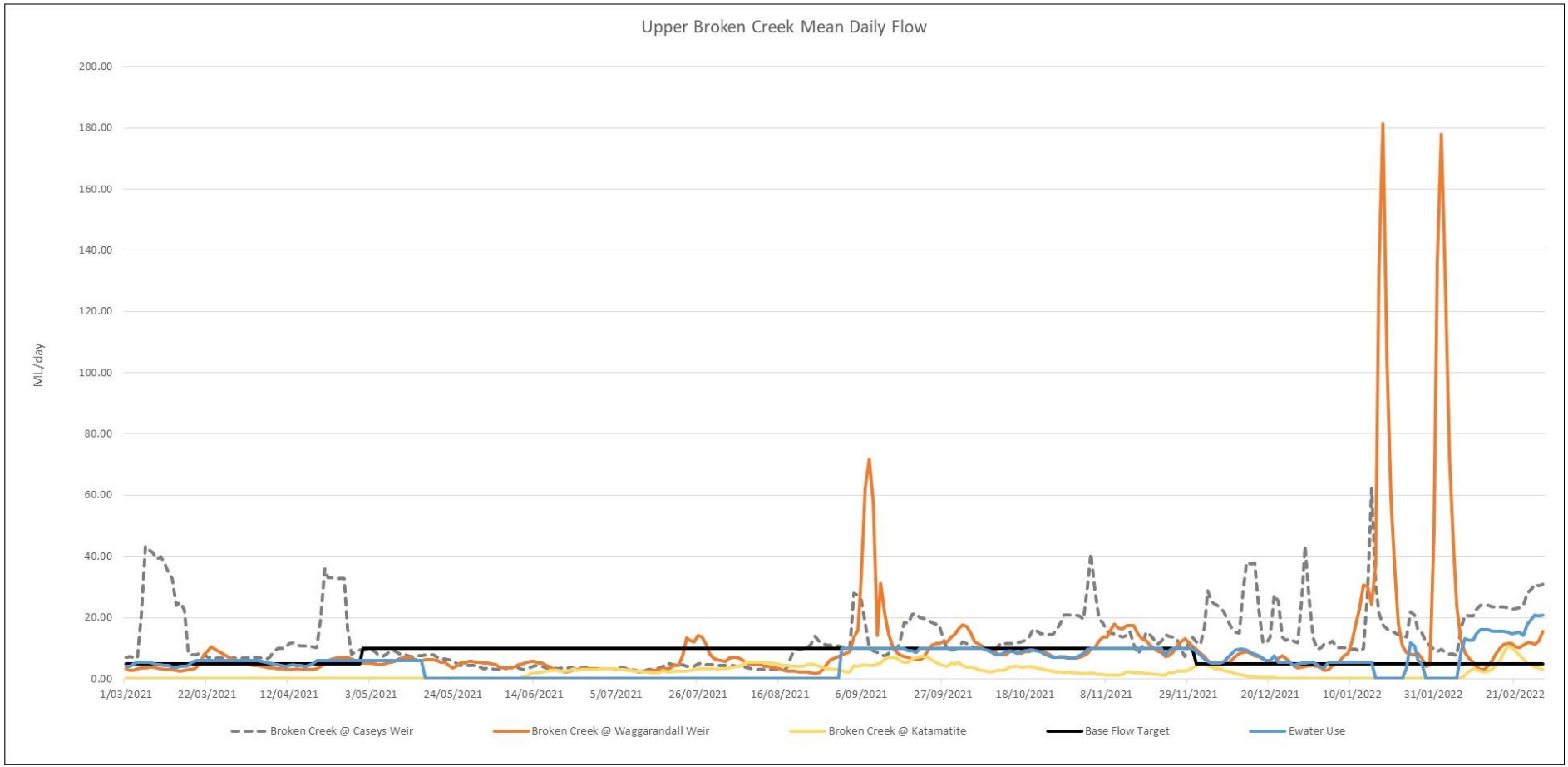


Figure 6 below shows the average daily flow (ML/day) at Waggarandall Weir from March 2021 to March 2022.

Figure 6: Upper Broken Creek flows from March 2021 to March 2022



Flow recommendations delivered

Broken River

Since 2011 all Broken River reaches have met the minimum low flow recommendation of 15 ML/day for most the time (see Table 6 below). Notable exceptions include reach 1 and reach 2 not meeting the minimum low flow recommendation for 42 days between May and June 2013 and 114 days in summer 2015-2016 respectively. Since 2011 reach 1 has only had 1 recommended summer/autumn fresh (see Table below) and reaches 2 and 3 have had 6 and 5 respectively.

Upper Broken Creek

In January 2015 a total of 387 ML of environmental water was used to maintain a flow of 50-100 ML/day in reach 1 of the upper Broken Creek to manage poor water quality. The water quality was impacted by ash and debris laden runoff entering the creek from the surrounding catchment which was burnt by a wildfire.

In February 2022 a total of 345 ML of environmental water was used to maintain a flow of 20-30 ML/day (measured at Caseys Weir at the top of reach 1) to help dilute black water and improve dissolved oxygen levels (see Upper Broken Creek section above for more details).

Since 2011 reach 1 of the upper Broken Creek has met or partially met the summer and autumn low flow recommendation in nine years and partially met the winter and spring low flow recommendation four and five times respectively (see Table 8).

Shared benefits review

The shared benefits (intrinsic or opportunistic) achieved in 2021-2022 through the delivery of environmental water in the upper Broken Creek and the Broken River are outlined in the table below.

Table 6: Shared benefits achieved in 2021-2022

Vale	Beneficiary	Description	Alignment with watering actions
• Recreational • Economic • Aboriginal cultural	• Fishers • Bird watchers • Irrigation diverters • Traditional Owners	Environmental water was used to supplement operations releases and unregulated flows to maintain minimum low flow requirements and deliver dilution flows to improve water quality impacted by hypoxic blackwater. These flows: • Provided habitat for native fish including favourable conditions for spawning, movement and larval survival. Maintaining a healthy native fish population increases recreational fishing opportunities. • Improved water quality and delivery efficiency of irrigation, stock and domestic water. This provided a benefit to licensed diverters. • Increased waterbird habitat along the	• Broken River year-round low flow • Upper Broken Creek summer, autumn, winter and spring low flows • Upper Broken Creek water quality flows

		upper Broken Creek increasing bird watching opportunities. • Helped to maintain and improve the health of the Broken River and upper Broken Creek. This supported Yorta Yorta Nation Aboriginal Corporation and Taungurung Land & Waters Council aspirations for these waterways outlined in their Land and Water Management Plans.	

Taungurung Land and Waters Council are planning to assess the Broken River's cultural values through an Aboriginal Waterway Assessment. The GB CMA will support this activity and the outcomes will help inform shared benefits of future Broken River environmental watering actions.

Table 7: Historical achievement of flow recommendations for the Broken River

Reach	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	2021-22 ecological observations
1	Low flow - 30-100 ML/day (minimum of 15 ML/d)	O/U	O/U	O/U	O/U	O/U	O/U	E/O	E/O/U	O/U	Operational releases and unregulated flows largely met or exceeded the minimum low flow recommendation in all reaches over the last 12 months. Wet condition also resulted in high variable baseflows between July and February. These flows would have achieved the desired objective of maintaining aquatic habitat for native fish, macrophytes, platypus and macroinvertebrates.
2	Low flow - 30-100 ML/day (minimum of 15 ML/d)	O/U	O/U	O/U	O/U	O/U	O/U	E/O	E/O/U	O/U	
3	Low flow - 30-100 ML/day (minimum of 15 ML/d)	O/U	O/U	O/U	O/U	O/U	O/U	E/O	E/O/U	O/U	
1	Summer/Autumn fresh - 400 ML/day					U	E/O			O/U	Reach 1 did not receive a fresh in summer. An autumn fresh may be delivered in autumn 2022 to meet this watering action if there is sufficient environmental water.
2	Summer/Autumn fresh - 400 ML/day	U			U	U	E/O		U	U	Unregulated flows in January resulted in 2 short duration freshes within 10 days of each other. Collectively, the freshes exceeded 400 ML/day for 4 days in reach 2 and 8 days in reach 3. Each individual fresh did not meet the recommendation of 400 ML/day for 5 days. However, the freshes likely achieved the desired objective of increasing in-channel habitat diversity and stimulating native fish movement.
3	Summer/Autumn fresh - 400 ML/day	U			U	U	E/O		U	U	
1	Summer/Autumn fresh - 500 ML/day					U					Reach 1 did not receive a fresh in summer. An autumn fresh may be delivered in autumn 2022 to

											meet this watering action if there is sufficient environmental water.

Table 8: Historical achievement of flow recommendations for the upper Broken Creek

Reach	Flow component	Hydrological achievement of flow components over time								
		2013-14	2014-15	2015-16	2016-17	2017-18	2018-19	2019-20	2021-21	2021-22	2021-22 ecological observations
1	Low flow - Summer 5 ML/day		O/U	O/U	O/U	O/U	O/U	E/O	E/O	E/O/U	The average daily flow at Waggarandall Weir was approximately 9 ML/day. This was a result of two overbank flow events and a higher baseflow during February in response to the blackwater event. Despite this, the average daily flow was less than 5 ML/day for 27 days (approximately 30% of the time).
1	Low flow - Autumn 5 ML/day		O/U	O/U	O/U	O/U	O/U	E/O	E/O	E/O	The average daily flow was 4.9 ML/day in summer. Despite not meeting the flow recommendation of 5 ML/day consistently, the baseflow likely achieved the desired objective of providing habitat for native fish, platypus and macroinvertebrates
1	Low flow - Winter 10 ML/day		O/U	O/U	O/U	O/U			E/O/U	O/U	The average daily flow was 4.6 ML/day in winter would have partially met the baseflow objective of providing habitat for native fish, platypus and macroinvertebrates.
1	Low flow - Spring 10 ML/day		O/U	O/U	O/U	O/U			E/O/U	E/O/U	The average daily flow was 13 ML/day in Spring. Despite not meeting the flow recommendation of 10 ML/day consistently, the baseflow likely achieved the desired objective of providing

											habitat for native fish, platypus and macroinvertebrates.

	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	U	Unregulated flows
O	Consumptive water on route/other managed flow	X	Unknown

Scenario Planning and Prioritisation

Climate Outlook for 2022-2023

According to the latest weather outlook information from the Bureau of Meteorology, April to June has a slightly higher chance of wetter than average conditions in the Goulburn and Broken Catchments. Lake Nillahcootie is currently 94% full and water is continuing to be released to meet irrigations demands. At the same time last year Lake Nillahcootie was only 81% full.

The current (February 2022) Broken system outlook for seasonal determinations indicate:

- an opening high security water share seasonal determination of 36 % in a wet Climate scenario, 6% in average scenario and 0% in dry and extreme dry scenarios;
- a high security water share seasonal determination of 100% by October 2022 in wet and average Climate scenarios and 22% in a dry Climate scenario; and
- a high security water share seasonal determination of 0% all season in an extreme Climate scenario.

This allocation outlook is similar to last years and is outlined in more detail in table 9 below.

Table 9: Broken system outlook for seasonal determination of high reliability shares

Climate Scenario	1 July 2022	15 August 2022	17 October 2022	15 February 2023
Wet	36%	39%	100%	100%
Average	6%	39%	100%	100%
Dry	0%	0%	22%	41%
Extreme Dry	0%	0%	0%	0%

Under all Climate scenarios, the volume of environmental water available is potentially much less than the volume required to deliver the desired priority watering actions. However, opportunities to use inter-valley water transfers in the Broken River to meet priority watering actions will be considered and environmental water holders can back trade water to provide additional water for environmental flows in the Broken River and upper Broken Creek.

Priority Watering Actions 2022-2023

The environmental flow targets in the Broken River water supply system are the Broken River, the upper Broken Creek and Moodie Swamp. The environmental water requirements of Moodie Swamp in 2022-2023 are dealt with in the Broken Wetlands Seasonal Watering Proposal 2022-2023.

The Broken River requires a minimum low flow of 15-30 ML/day throughout the year to maintain critical habitat for native fish, macroinvertebrates and aquatic plants. Operational releases and unregulated flows are expected to meet the minimum low flow requirements next year in average and wet climate scenarios. However, operational releases and unregulated flows are unlikely to meet all the minimum low flow requirement next year under dry and extreme dry climate scenarios, particularly outside of the irrigation season.

The Broken River requires an annual summer or autumn fresh with a peak discharge of 400-500 ML/day in all reaches to promote: in-channel habitat diversity; native fish and macrophyte health and recruitment; and biofilm production. Since 2011 reach 1 of the Broken River has only had 1 recommended summer or autumn fresh and reaches 2 and 3 have had 6 and 5 respectively. The frequency of these freshes, particularly in reach 1, has been reduced by the operation of Lake Nillahcootie. Reach 1 is unlikely to receive a summer or autumn fresh in all but wet years and may be dependent on Lake Nillahcootie spilling. Reaches 2 and 3 are likely to receive a summer or autumn fresh in average and wet climate scenarios.

Reach 1 of the upper Broken Creek requires minimum low flows of 5-10 ML/day (measured at Waggarandall Weir at the bottom of reach 1) throughout the year to maintain critical habitat for native fish, macroinvertebrates, platypus and aquatic plants. These low flows also help maintain the ecological values of the downstream reaches. Unregulated flows and operational releases are likely to contribute part or all the minimum low flow requirements in average and wet climate scenarios. However, unregulated flows and operational releases are unlikely to make a meaningful contribution to the minimum low flow requirements under dry and extreme dry climate scenarios.

Short term releases between 50-100 ML/day into the top of reach 1 may be required to respond to poor water quality. This could be the result of floods, low and cease to flow events, intense rainfall and fire. These events are more likely to occur in summer and early autumn and can impact native fish, platypus and macroinvertebrate habitat.

Despite the small volume of environmental water available in the Broken River system, saving environmental water for the 2022-2023 year may assist in providing critical low flow requirements under dry and extreme inflow conditions.

The priority watering actions will improve the social amenity of the upper Broken Creek and Broken River by improving water quality and recreational opportunities. No negative social or economic impacts associated with the priority watering actions have been identified.

The proposed watering actions are summarised and prioritised in Table below.

Table 10: Summary of priority watering actions

Upper Broken Creek – priority 1a and 1b watering action				
Target reach:	Reach 1: Reach 1 is a priority to receive environmental water in 2022-23 as it supports a more diverse and abundant native fish community than reaches 2 and 3. Reach 1 also supports a large permanent platypus population. Environmental water delivered to reach 1 will provide environmental benefits to reaches 2 and 3.			
Compliance point	Waggarandall Weir			
Potential watering action	Upper Broken Creek spring low flow: 10 ML/day Note: the low flow may be reduced to 1-9 ML/day to accommodate available water resources			
Expected watering effects	• Provides suitable water depth in the channel and good connection between weir pools for native fish and platypus. • Inundate benthic surfaces and large wood located in the bottom of the channel which provides habitat for macroinvertebrates. • Suitable water quality (DO) is maintained for native fish, platypus and macroinvertebrates. • Flow may reach the lower Broken Creek and increase the opportunity for movement of aquatic biota between the waterways.			
Environmental objectives	• Maintain conditions for self-sustaining populations of native fish. • Maintain self-sustaining populations of macroinvertebrates. • Maintain the platypus population and support successful breeding and juvenile dispersal.			
Climate scenario variations	Extreme dry	Dry	Average	Wet
Required	·	·	·	·
Volume (ML)	910	910	546	546
Assumption	Flow of 10 ML/day for 91 days Limited or no operational release and unregulated flows. May require the release of 10 ML/day to achieve a passing flow of 10 ML/day at Waggarandall Weir	Flow of 10 ML/day for 91 days Limited or no operational release and unregulated flows. May require the release of 10 ML/day to achieve a passing flow of 10 ML/day at Waggarandall Weir	Flow of 6 ML/day for 91 days Limited or no operational release and unregulated flows. May require the release of 6 ML/day to achieve a passing flow of 10 ML/day at Waggarandall Weir	Flow of 6 ML/day for 91 days Limited or no operational release and unregulated flows. May require the release of 6 ML/day to achieve a passing flow of 10 ML/day at Waggarandall Weir
Rationale for delivery in 2022-23	If the spring low flow is not delivered operational releases and unregulated flows may only provide limited habitat for native fish, platypus and macroinvertebrates (water depth, connectivity and quality). This may have a negative impact on their health and recruitment. A low flow of 1-9 ML/day is expected to increase the availability of habitat suitable for native fish, platypus and macroinvertebrates. This will reduce risk of poor health and recruitment outcomes.			

Upper Broken Creek – priority 1a and 1b watering action				
Target reach:	Reach 1: Reach 1 is a priority to receive environmental water in 2022-23 as it supports a more diverse and abundant native fish community than reaches 2 and 3. Reach 1 also supports a large permanent platypus population. Environmental water delivered to reach 1 will provide environmental benefits to reaches 2 and 3.			
Compliance point	Waggarandall Weir			
Potential watering action	Upper Broken Creek summer low flow: 5 ML/day Note: the low flow may be reduced to 1-4 ML/day to accommodate available water resources			
Expected watering effects	• Provides suitable water depth in the channel and some connection between weir pools for native fish and platypus. • Inundate benthic surfaces and large wood located in the bottom of the channel which provides habitat for macroinvertebrates. • Suitable water quality (DO) is maintained for native fish, platypus and macroinvertebrates.			
Environmental objectives	• Maintain conditions for self-sustaining populations of native fish. • Maintain self-sustaining populations of macroinvertebrates. • Maintain the platypus population and support successful breeding and juvenile dispersal.			
Climate scenario variations	Extreme dry	Dry	Average	Wet
Required	.	.	.	.
Volume (ML)	720	720	270	270
Assumption	Flow of 8 ML/day for 90 days Limited or no operational release and unregulated flows. May require the release of 8 ML/day to achieve a passing flow of 5 ML/day at Waggarandall Weir	Flow of 8 ML/day for 90 days Limited or no operational release and unregulated flows. May require the release of 8 ML/day to achieve a passing flow of 5 ML/day at Waggarandall Weir	Flow of 3 ML/day for 90 days May require the release of 3 ML/day to supplement operational releases and unregulated flows to achieve a passing flow of 5 ML/day at Waggarandall Weir	Flow of 3 ML/day for 90 days May require the release of 3 ML/day to supplement operational releases and unregulated flows to achieve a passing flow of 5 ML/day at Waggarandall Weir
Rationale for delivery in 2022-23	Operational releases and unregulated flows may only provide limited habitat for native fish, platypus and macroinvertebrates (water depth, connectivity and quality). This may have a negative impact on their health and recruitment. A low flow of 1-4 ML/day is expected to increase the availability of habitat suitable for native fish, platypus and macroinvertebrates. This will reduce risk of poor health and recruitment outcomes.			

Upper Broken Creek – priority 1a and 1b watering action				
Target reach:	Reach 1: Reach 1 is a priority to receive environmental water in 2022-23 as it supports a more diverse and abundant native fish community than reaches 2 and 3. Reach 1 also supports a large permanent platypus population. Environmental water delivered to reach 1 will provide environmental benefits to reaches 2 and 3.			
Compliance point	Waggarandall Weir			
Potential watering action	Upper Broken Creek autumn low flow: 5 ML/day Note: the low flow may be reduced to 1-4 ML/day to accommodate available water resources			
Expected watering effects	• Provides suitable water depth in the channel and some connection between weir pools for native fish and platypus. • Inundate benthic surfaces and large wood located in the bottom of the channel which provides habitat for macroinvertebrates. • Suitable water quality (DO) is maintained for native fish, platypus and macroinvertebrates.			
Environmental objectives	• Maintain conditions for self-sustaining populations of native fish. • Maintain self-sustaining populations of macroinvertebrates. • Maintain the platypus population and support successful breeding and juvenile dispersal.			
Climate scenario variations	Extreme dry	Dry	Average	Wet
Required	·	·	·	·
Volume (ML)	720	720	270	270
Assumption	Flow of 8 ML/day for 90 days Limited or no operational release and unregulated flows. May require the release of 8 ML/day to achieve a passing flow of 5 ML/day at Waggarandall Weir	Flow of 8 ML/day for 90 days Limited or no operational release and unregulated flows. May require the release of 8 ML/day to achieve a passing flow of 5 ML/day at Waggarandall Weir	Flow of 3 ML/day for 90 days May require the release of 3 ML/day to supplement operational releases and unregulated flows to achieve a passing flow of 5 ML/day at Waggarandall Weir	Flow of 3 ML/day for 90 days May require the release of 3 ML/day to supplement operational releases and unregulated flows to achieve a passing flow of 5 ML/day at Waggarandall Weir
Rationale for delivery in 2022-23	Operational releases and unregulated flows may only provide limited habitat for native fish, platypus and macroinvertebrates (water depth, connectivity and quality). This may have a negative impact on their health and recruitment. For example, juvenile platypuses require connected habitat in autumn to facilitate safe dispersal. A low flow of 1-4 ML/day is expected to increase the availability of habitat suitable for native fish, platypus and macroinvertebrates. This will reduce risk of poor health and recruitment outcomes.			

Upper Broken Creek – priority 1a and 1b watering action				
Target reach:	Reach 1: Reach 1 is a priority to receive environmental water in 2022-23 as it supports a more diverse and abundant native fish community than reaches 2 and 3. Reach 1 also supports a large permanent platypus population. Environmental water delivered to reach 1 will provide environmental benefits to reaches 2 and 3.			
Compliance point	Waggarandall Weir			
Potential watering action	Upper Broken Creek winter low flow: 10 ML/day Note: the low flow may be reduced to 1-9 ML/day to accommodate available water resources			
Expected watering effects	• Provides suitable water depth in the channel and good connection between weir pools for native fish and platypus. • Inundate benthic surfaces and large wood located in the bottom of the channel which provides habitat for macroinvertebrates. • Suitable water quality (DO) is maintained for native fish, platypus and macroinvertebrates.			
Environmental objectives	• Maintain conditions for self-sustaining populations of native fish. • Maintain self-sustaining populations of macroinvertebrates. • Maintain the platypus population and support successful breeding and juvenile dispersal. • Flow may reach the lower Broken Creek and increase the opportunity for movement of aquatic biota between the waterways.			
Climate scenario variations	Extreme dry	Dry	Average	Wet
Required	·	·	·	·
Volume (ML)	910	910	546	546
Assumption	Flow of 10 ML/day for 91 days Limited or no operational release and unregulated flows. May require the release of 10 ML/day to achieve a passing flow of 10 ML/day at Waggarandall Weir	Flow of 10 ML/day for 91 days Limited or no operational release and unregulated flows. May require the release of 10 ML/day to achieve a passing flow of 10 ML/day at Waggarandall Weir	Flow of 6 ML/day for 91 days Limited or no operational release and unregulated flows. May require the release of 6 ML/day to achieve a passing flow of 10 ML/day at Waggarandall Weir	Flow of 6 ML/day for 91 days Limited or no operational release and unregulated flows. May require the release of 6 ML/day to achieve a passing flow of 10 ML/day at Waggarandall Weir
Rationale for delivery in 2022-23	Operational releases and unregulated flows may only provide limited habitat for native fish, platypus and macroinvertebrates (water depth, connectivity and quality). This may have a negative impact on their health and recruitment. A low flow of 1-9 ML/day is expected to increase the availability of habitat suitable for native fish, platypus and macroinvertebrates. This will reduce risk of poor health and recruitment outcomes.			

Upper Broken Creek – priority 1b watering action				
Target reach:	Reach 1: Reach 1 is a priority to receive environmental water in 2022-23 as it supports a more diverse and abundant native fish community than reaches 2 and 3. Reach 1 also supports a large permanent platypus population. Environmental water delivered to reach 1 will provide environmental benefits to reaches 2 and 3.			
Compliance point	Waggarandall Weir			
Potential watering action	Upper Broken Creek water quality management flows: 50-100 ML/day			
Expected watering effects	• Water quality (DO) is maintained for native fish, platypus and macroinvertebrates.			
Environmental objectives	• Maintain conditions for self-sustaining populations of native fish. • Maintain self-sustaining populations of macroinvertebrates. • Maintain the platypus population and support successful breeding and juvenile dispersal.			
Climate scenario variations	Extreme dry	Dry	Average	Wet
Required	·	·	·	·
Volume (ML)	500-1000	500-1000	500-1000	500-1000
Assumption	Flow of 50-100 ML/day for 10 days Short high pulses of water will be effective in maintaining water quality	Flow of 50-100 ML/day for 10 days Short high pulses of water will be effective in maintaining water quality	Flow of 50-100 ML/day for 10 days Short high pulses of water will be effective in maintaining water quality	Flow of 50-100 ML/day for 10 days Short high pulses of water will be effective in maintaining water quality
Rationale for delivery in 2022-23	This watering action may be required to manage poor water quality. This could be the result of floods, low and cease to flow events, intense rainfall and fire.			

Broken River – priority 1a and 1b watering action				
Target reach:	All 3 reaches			
Compliance points	• Back Creek Junction in reach 1 • Caseys Weir in reach 2 • Gowangardie Weir in reach 3			
Potential watering action	Broken River spring low flow: 15-30 ML/day			
Expected watering effects	• Permanent inundation of the channel which allows obligate submerged native plants to establish and reduces invasion of flood tolerant species. • Provides suitable water depth and flow to maintain riffles, run, pool and slackwater habitats. • Suitable water quality (DO) is maintained for native fish, platypus and macroinvertebrates.			
Environmental objectives	• Maintain hydraulic habitat diversity (riffles, slackwater and pools) which supports native fish, macrophytes and macroinvertebrates.			
Climate scenario variations	Extreme dry	Dry	Average	Wet
Required	·	·	·	·
Volume (ML)	75-600	75-600	0	0
Assumption	Flow of 5-40 ML/day for 15 days May require the release of 20 ML/day to achieve a passing flow of 15 ML/day at Gowangardie Weir May require the release of 40 ML/day to achieve a passing flow of 30 ML/day at Gowangardie Weir	Flow of 5-40 ML/day for 15 days May require the release of 20 ML/day to achieve a passing flow of 15 ML/day at Gowangardie Weir May require the release of 40 ML/day to achieve a passing flow of 30 ML/day at Gowangardie Weir	Low flow expected to ill be met by operational releases and unregulated flows	Low flow expected to be met by operational releases and unregulated flows
Rationale for delivery in 2022-23	Operational releases and unregulated flows may only provide limited habitat for native fish, platypus and macroinvertebrates (water depth, connectivity and quality), particularly in reach 1. This may have a negative impact on their health and recruitment.			

Broken River – priority 1a and 1b watering action				
Target reach:	All 3 reaches			
Compliance points	• Back Creek Junction in reach 1 • Caseys Weir in reach 2 • Gowangardie Weir in reach 3			
Potential watering action	Broken River summer low flow: 15-30 ML/day			
Expected watering effects	• Permanent inundation of the channel which allows obligate submerged native plants to establish and reduces invasion of flood tolerant species. • Provides suitable water depth and flow to maintain riffles, run, pool and slackwater habitats. • Suitable water quality (DO) is maintained for native fish, platypus and macroinvertebrates.			
Environmental objectives	• Maintain hydraulic habitat diversity (riffles, slackwater and pools) which supports native fish, macrophytes and macroinvertebrates.			
Climate scenario variations	Extreme dry	Dry	Average	Wet
Required	·	·	·	·
Volume (ML)	75-600	75-600	0	0
Assumption	Flow of 5-40 ML/day for 15 days May require the release of 20 ML/day to achieve a passing flow of 15 ML/day at Gowangardie Weir May require the release of 40 ML/day to achieve a passing flow of 30 ML/day at Gowangardie Weir	Flow of 5-40 ML/day for 15 days May require the release of 20 ML/day to achieve a passing flow of 15 ML/day at Gowangardie Weir May require the release of 40 ML/day to achieve a passing flow of 30 ML/day at Gowangardie Weir	Low flow expected to be met by operational releases and unregulated flows	Low flow expected to be met by operational releases and unregulated flows
Rationale for delivery in 2022-23	Operational releases and unregulated flows may only provide limited habitat for native fish, platypus and macroinvertebrates (water depth, connectivity and quality), particularly in reach 1. This may have a negative impact on their health and recruitment.			

Broken River – priority 1a and 1b watering action				
Target reach:	All 3 reaches			
Compliance points	• Back Creek Junction in reach 1 • Caseys Weir in reach 2 • Gowangardie Weir in reach 3			
Potential watering action	Broken River autumn low flow: 15-30 ML/day			
Expected watering effects	• Permanent inundation of the channel which allows obligate submerged native plants to establish and reduces invasion of flood tolerant species. • Provides suitable water depth and flow to maintain riffles, run, pool and slackwater habitats. • Suitable water quality (DO) is maintained for native fish, platypus and macroinvertebrates.			
Environmental objectives	• Maintain hydraulic habitat diversity (riffles, slackwater and pools) which supports native fish, macrophytes and macroinvertebrates.			
Climate scenario variations	Extreme dry	Dry	Average	Wet
Required	·	·	·	·
Volume (ML)	75-600	75-600	0	0
Assumption	Flow of 5-40 ML/day for 15 days May require the release of 20 ML/day to achieve a passing flow of 15 ML/day at Gowangardie Weir May require the release of 40 ML/day to achieve a passing flow of 30 ML/day at Gowangardie Weir	Flow of 5-40 ML/day for 15 days May require the release of 20 ML/day to achieve a passing flow of 15 ML/day at Gowangardie Weir May require the release of 40 ML/day to achieve a passing flow of 30 ML/day at Gowangardie Weir	Low flow expected to be met by operational releases and unregulated flows	Low flow expected to be met by operational releases and unregulated flows
Rationale for delivery in 2022-23	Operational releases and unregulated flows may only provide limited habitat for native fish, platypus and macroinvertebrates (water depth, connectivity and quality), particularly in reach 1. This may have a negative impact on their health and recruitment. For example, juvenile platypuses require connected habitat in autumn to facilitate safe dispersal.			

Broken River – priority 1a and 1b watering action				
Target reach:	All 3 reaches			
Compliance points	• Back Creek Junction in reach 1 • Caseys Weir in reach 2 • Gowangardie Weir in reach 3			
Potential watering action	Broken River winter low flow: 15-30 ML/day			
Expected watering effects	• Permanent inundation of the channel which allows obligate submerged native plants to establish and reduces invasion of flood tolerant species. • Provides suitable water depth and flow to maintain riffles, run, pool and slackwater habitats. • Suitable water quality (DO) is maintained for native fish, platypus and macroinvertebrates.			
Environmental objectives	• Maintain hydraulic habitat diversity (riffles, slackwater and pools) which supports native fish, macrophytes and macroinvertebrates.			
Climate scenario variations	Extreme dry	Dry	Average	Wet
Required	·	·	·	·
Volume (ML)	75-600	75-600	0	0
Assumption	Flow of 5-40 ML/day for 15 days May require the release of 20 ML/day to achieve a passing flow of 15 ML/day at Gowangardie Weir May require the release of 40 ML/day to achieve a passing flow of 30 ML/day at Gowangardie Weir	Flow of 5-40 ML/day for 15 days May require the release of 20 ML/day to achieve a passing flow of 15 ML/day at Gowangardie Weir May require the release of 40 ML/day to achieve a passing flow of 30 ML/day at Gowangardie Weir	Low flow expected to be met by operational releases and unregulated flows	Low flow expected to be met by operational releases and unregulated flows
Rationale for delivery in 2022-23	Operational releases and unregulated flows may only provide limited habitat for native fish, platypus and macroinvertebrates (water depth, connectivity and quality), particularly in reach 1. This may have a negative impact on their health and recruitment.			

Broken River – priority 1b watering action				
Target reach:	All 3 reaches			
Compliance points	• Back Creek Junction in reach 1 • Caseys Weir in reach 2 • Gowangardie Weir in reach 3			
Potential watering action	Broken River summer or autumn fresh: 400-500 ML/day for 2-5 days			
Expected watering effects	• Provide sufficient critical shear stress to turn over bed sediments, scour around large wood and remove biofilm • Provide a mosaic of habitats suitable for macrophyte colonisation. • Provide flow of sufficient magnitude to stimulate native fish breeding and movement. • Provides suitable water depth and increase habitat connectivity to promote fish passage.			
Environmental objectives	• Turn over bed sediments and scour around large wood. • Provide flow cues to stimulate native fish breeding and migration movements. • Promote biofilm productivity. • Maintain macrophyte habitat. • Provide habitat for native fish passage.			
Climate scenario variations	Extreme dry	Dry	Average	Wet
Required	NA	·	·	·
Volume (ML)	0	2,390-5,800	2,390-5,800	0
Assumption	Would not naturally occur under the extreme dry climate scenario	Flow of 400-500 ML/day for 2-5 days with rates of rise and fall and a base flow of 30 ML/day	Flow of 400-500 ML/day for 2-5 days with rates of rise and fall and a base flow of 30 ML/day	Fresh expected to be met by operational releases and unregulated flows
Rationale for delivery in 2022-23	Since 2011 reach 1 has only had 1 recommended summer/autumn fresh and reaches 2 and 3 have had 5 and 4 respectively. Not delivering the fresh is expected to have a negative impact on the health and recruitment of macrophytes, native fish and macroinvertebrates. However, there is no monitoring program in place to assess this.			

1a Critically important actions that should be partly or completely achievable based on estimates of available water resources
1b Critically important actions that are unlikely to be achievable based on estimates of available water resources
2 Actions expected to improve environmental outcomes, but are unlikely to result in negative environmental outcomes if they are not delivered this year

Scenario Planning

The Broken River system has a highly variable flow, depending on catchment runoff and the operation of the water supply delivery system. Environmental flow management aims to allow catchment runoff and operational releases to meet as many priority watering actions as possible, and then deploy water from environmental entitlements into the highest priority gaps that remain. However, under different possible climate scenarios (from dry to wet), the environmental flow gaps move dramatically and the deployment of environmental water changes. Therefore, plans are prepared for a range of possible climate scenarios to understand how the priorities and required volumes for deployment of environmental water change.

The scenarios are based on current conditions such as the volumes of water in storage and they assume the availability of all environmental water entitlements and their associated water allocations in the Broken River system. The scenarios then determine how best to maximise the environmental outcomes from their use.

In most cases, the volumes available are much smaller than the desirable priority watering actions and more water could be used if available.

Importantly, the planning is not concerned with the probability of any particular climate scenario (or in picking the most likely scenario) it merely ensures there is a plan if any scenario does occur. While various climate scenario indicators exist, predicting the conditions for the coming season (both winter/spring and summer/autumn) is not reliable.

The scenarios have been picked to highlight the key decisions that will need to be made about environmental water deployment for 2022-2023. The scenarios range from the driest conditions to the wettest. Importantly, the actual management of water through the season must be adaptive, with water deployment decisions adjusting as the season unfolds, particularly in response to timing issues within the season. Table 11 outlines the range of scenarios for water use in the Broken River system in 2022-2023.

Summer storms in 2010-2011, 2011-2012, 2016-17 and 2021-2022 produced significant runoff in the Broken River catchment. These events are erratic in nature, and not correlated with the climate scenarios above (which are based on winter/spring rainfall). The scenarios assume these events do not occur. If one or more events do occur, they will potentially reduce the need for environmental water to be delivered down the upper Broken Creek and Broken River in summer/autumn. The VEWH and or CEWO can also back trade water into the system (if available) to help meet a shortfall if required.

Triggers for action

This GB CMA proposal is based on using the seasonal allocation of all environmental entitlements expected to be available in the Broken River system in 2022-2023 (outlined in Table 1) including up to 1,500 ML of back trade. The volume that can be back traded by the VEWH may be less or greater than 1,500 ML, but for the purposes of planning this volume is used. The use of banked water and or the delivery of trade commitments to meet priority watering actions has not been considered due to the uncertainty around their availability.

Upper Broken Creek

The highest priority is to maintain spring and summer minimum low flows in the upper Broken Creek (in all climate scenarios). Spring and summer are the most important periods for instream production and native fish, macroinvertebrate and platypus movement and reproduction. Summer low flows also help to maintain water quality, which is often at greatest risk at this time of the year due to high ambient temperatures. There will only be sufficient environmental water and back trade opportunities to fully meet this requirement under wet and average climate scenarios. There may be sufficient environmental water in the dry climate scenario to deliver a reduced spring base flow.

The next priority is to maintain the autumn low flow in the upper Broken Creek (in all climate scenarios) followed by maintaining the winter minimum low flow in the upper Broken Creek (in all climate scenarios). Autumn is an important time for dispersal of juvenile platypus and is relatively important for instream production. There may be sufficient environmental water and back trade opportunities to meet autumn and winter minimum low flows under average and wet climate scenarios.

The final priority is to maintain water quality in the upper Broken Creek to support native fish, platypus and macroinvertebrates under all climate scenarios. This involves delivering water in response to extreme weather or flows that may cause poor water quality (e.g., floods, low and cease to flow events, intense rainfall and fire). Flow, weather and dissolved oxygen levels will be monitored to inform the timing and need for this action. The need to deliver this priority is more likely under the extreme dry and dry climate scenarios. Under both scenarios there will be insufficient environmental water and back trade opportunities to meet the water requirements. However, if the other priority watering actions are not triggered environmental water and back trade could be used to deliver this watering action.

Broken River

The highest priority is to maintain spring and summer low flows in all reaches of the Broken Rive (in all climate scenarios). Spring and summer are the most important periods for instream production and native fish, macroinvertebrate and platypus movement and reproduction. Summer low flows also help to maintain water quality, which is often at greatest risk at this time of the year due to high ambient temperatures.

The next priority is to maintain the autumn low flow in all reaches of the Broken River (in all climate scenarios) followed by maintaining the winter low flow in in all reaches (in all climate scenarios). Autumn is an important time for dispersal of juvenile platypus and is relatively important for instream production.

There may not be sufficient environmental water and back trade opportunities to meet these priority watering actions under extreme dry and dry climate scenarios. Under average and wet climate scenarios operational releases and unregulated flows are expected to meet the low flow requirements.

The final priority is to deliver a summer or autumn fresh in reach 1 of the Broken River in dry and average climate scenarios (this priority watering action may be met by unregulated flows in a wet climate scenario). Under both climate scenarios there will be insufficient environmental water and back trade opportunities to meet the water requirements. However, if the other priority watering actions are not triggered environmental water and back trade could be used to deliver a modified fresh.

Flow, the trade water balance, seasonal determinations and the weather will be monitored by the GB CMA throughout the year to inform the timing and need for upper Broken Creek and Broken River priority watering actions. Where priory watering actions in the upper Broken Creek and Broken River are competing for water, they may be modified to meet the available water resources or prioritised in consultation with technical experts based on risk.

Table 11: Scenario planning summary

	Scenario 1 EXTREME DRY 99% POE	Scenario 2 DRY 90% POE	Scenario 3 AVERAGE 50% POE	Scenario 4 WET 30% POE
Water resources and flow conditions				
Water Supply	0% high reliability water supply allocations Irrigation season may be shortened Carry over may not be available at the start of the season	35% high reliability water supply allocations by February Irrigation season may be shortened Carry over may not be available at the start of the season	100% high reliability water supply allocations by October and 100% low reliability water supply allocations by December Carry over available at the start of the season	100% high reliability water supply allocations by October and 100% low reliability water supply allocations by December Carry over available at the start of the season
Expected Unregulated Flow and Water Management	No Broken River unregulated flows in winter/spring	Low unregulated flows and odd freshes in the Broken River	High winter/spring flows in the Broken River	Winter/spring floods in the Broken River
	Low/minimum Broken River operational releases (or natural)	Low/minimum Broken River operational releases (or natural)	Normal minimum Broken River operational releases (or natural)	Normal minimum Broken River operational releases (or natural)
	0-10 ML/day Broken River flows, with ~50 ML/day flows Dec-Apr	0-10 ML/day Broken River flows, with ~50 ML/day flows Dec-Apr	~50-100 ML/day Broken River flows Dec-Apr	~50-100 ML/day Broken River flows Dec-Apr
	No unregulated flows in upper Broken Creek	No unregulated flows in upper Broken Creek	Some unregulated winter/spring flows in upper Broken Creek	Winter/spring freshes in upper Broken Creek
	0-5 ML/day operational releases from Caseys Weir into upper Broken Creek Low and cease-to-flow events possible throughout the year in all reaches	0-5 ML/day operational releases from Caseys Weir into upper Broken Creek Low and cease-to-flow events possible throughout the year in all reaches	5-15 ML/day operational releases from Caseys Weir into upper Broken Creek plus flows up to 30 ML/day in summer	5-15 ML/day operational releases from Caseys Weir into upper Broken Creek plus flows up to 30 ML/day in summer
	No back trade opportunities	No back trade opportunities	1,500 ML of back trade available in the Broken River from October	1,500 ML of back trade available in the Broken River from October
Environmental Entitlement Volumes Available	0 ML[1] (0 allocation and no carryover)	226 ML[1] (0 allocation and no carryover)	647 ML[2] (625 HRWS + 22.9 LRWS)	647 ML[2] (625 HRWS + 22.9 LRWS)
Upper Broken Creek Priority Watering Actions				

	Scenario 1 EXTREME DRY 99% POE	Scenario 2 DRY 90% POE	Scenario 3 AVERAGE 50% POE	Scenario 4 WET 30% POE
Priority 1a	• NA	• Upper Broken Creek spring low flow at 10 ML/day	• Upper Broken Creek summer low flow at 5 ML/day • Upper Broken Creek autumn low flow at 5 ML/day • Upper Broken Creek winter low flow at 10 ML/day	• Upper Broken Creek summer low flow at 5 ML/day • Upper Broken Creek autumn low flow at 5 ML/day • Upper Broken Creek winter low flow at 10 ML/day
Priority 1b	• Upper Broken Creek spring low flow at 10 ML/day • Upper Broken Creek summer low flow at 5 ML/day • Upper Broken Creek autumn low flow at 5 ML/day • Upper Broken Creek winter low flow at 10 ML/day • Upper Broken Creek water quality management flows at 50-100 ML/day[3]	• Upper Broken Creek summer low flow at 5 ML/day • Upper Broken Creek autumn low flow at 5 ML/day • Upper Broken Creek winter low flow at 10 ML/day • Upper Broken Creek water quality management flows at 50-100 ML/day[3]	• Upper Broken Creek water quality management flows at 50-100 ML/day[3]	• Upper Broken Creek water quality management flows at 50-100 ML/day[3]
Priority 2	• NA	• NA	• NA	• NA
Total Water Requirements	**3,776 – 4,276 ML**	**3,776 – 4,276 ML**	**2,138 – 2,638 ML**	**2,138 – 2,638 ML**
Broken River Priority Watering Actions				
Priority 1a	• NA	• NA	• Broken River spring low flow at 15-30 ML/day • Broken River summer low flow at 15-30 ML/day • Broken River autumn low flow at 15-30 ML/day • Broken River winter low flow at 15-30 ML/day	• Broken River spring low flow at 15-30 ML/day • Broken River summer low flow at 15-30 ML/day • Broken River autumn low flow at 15-30 ML/day • Broken River winter low flow at 15-30 ML/day
Priority 1b	• Broken River spring low flow at 15-30 ML/day	• Broken River spring low flow at 15-30 ML/day	• Broken River summer or autumn fresh at 400-500 ML/day for 2-5 days	• NA

	Scenario 1 EXTREME DRY 99% POE	Scenario 2 DRY 90% POE	Scenario 3 AVERAGE 50% POE	Scenario 4 WET 30% POE
	• Broken River summer low flow at 15-30 ML/day • Broken River autumn low flow at 15-30 ML/day • Broken River winter low flow at 15-30 ML/day	• Broken River summer low flow at 15-30 ML/day • Broken River autumn low flow at 15-30 ML/day • Broken River winter low flow at 15-30 ML/day • Broken River summer or autumn fresh at 400-500 ML/day for 2-5 days		
Priority 2	• NA	• NA	• NA	• NA
Total Water Requirements	**300 – 2,400 ML**	**2,690 – 8,200 ML**	**2,390 – 5,800 ML**	**0 ML**
Total Potential Water Shortfall[4]	**4,076 – 6,676 ML**	**5,715 – 11,724 ML**	**2,380 – 6,290 ML**	**0 – 490 ML**

1. Maximum carry over in the Broken System is 50% of the high reliability water share entitlement volume.
2. High reliability allocation and carry over cannot exceed the high reliability water share entitlement volume.
3. Assumes only one delivery event is required.
4. Environmental water shortfall is the accumulative water shortfall and considers the volume of environmental entitlement available and the expected volume of water that can be back traded (1,500 ML)

Delivery Constraints

Delivery of environmental water down the Broken River is primarily constrained by water availability. In most cases the volume of environmental water available is much less than the volume required to deliver the desired priority watering actions.

The channel capacity in reach 1 of the Broken River is approximately 4,000 ML/day, 16,000 ML/day in reach 2 and 20,000 ML/day in reach 3. However, flows above 400-500 ML/day in reach 1 of the Broken River may impact on private irrigation infrastructure in the channel and access tracks. Until GMW and the GB CMA can more accurately determine the impact of flows above 400-500 ML/day on private irrigation infrastructure in reach 1, environmental water deliveries will be restricted to 400-500 ML/d or less.

The Bulk Entitlement (Broken System – Goulburn-Murray Water) Conversion Order 2004 previously restricted Inter-valley water Transfers to a maximum rate of 90 ML/day between December and March. However, the Bulk Entitlement (Broken System – Goulburn-Murray Water) Conversion Order 2004 was amended in 2017 to allow:

- Inter-valley water Transfers greater than 90 ML/day to be temporarily delivered between December and March upon agreement between GMW and the GB CMA.
- Minimum and maximum environmental flows to be temporarily modified upon agreement between GMW and the GB CMA.

In the upper Broken Creek delivery of environmental water is primarily restricted by channel capacity. Modelling undertaken as part of the 2017 Flows Study (Jacobs 2017) suggested channel capacity at a couple of locations downstream of Waggarandall Weir (reach 2) is restricted to approximately 10 ML/d. Until GMW and the GB CMA can more accurately determine the channel capacity in reach 2, environmental water deliveries will be restricted to 10 ML/d or less at Waggarandall Weir to avoid nuisance flooding of adjacent land.

Implementation arrangements

No formal operating arrangements exist for the Broken River system. However, deliveries are guided by the Broken System Bulk Entitlement. System capacity constraints are unlikely when supplying these small volumes of environmental water and GMW will consult with GB CMA should limitations occur.

Costs

The Environmental Water Manager does not have to make any payment for headworks costs relating to the environmental entitlements or the Bulk Entitlement (Broken System – Goulburn-Murray Water) Conversion Order 2004. The environmental water holders pay the relevant headworks cost associated with the entitlements they hold.

Notice and time required

A minimum notice period of one to two days, and preferably four days, is required for environmental water orders from Broken River system storages. If GMW foresees constraints in making environmental water available, the GB CMA Environmental Water Manager will be advised accordingly. Releases from Lake Nillahcootie take approximately two days to reach Caseys Weir. Releases from Caseys Weir to the Broken Creek could take a week to pass Waggarandall Weir. However, this can be influenced by existing conditions in the river and creek channel and seasonal conditions.

Confounding Factors

The Broken River system has been modified by regulation, changes in land use practice, land clearing and pest invasion. Below are the key confounding factors that continue to hinder achievement of the environmental water objectives for the system and what mitigating actions are currently planned.

Table 12: Confounding factors hindering achievement of environmental water objectives

Ecological value	Confounding factors	Mitigating actions planned
Native fish Macrophytes Macroinvertebrates	Introduced carp compete with native fish species for habitat and reduce water quality.	The status of the planned release of the Carp Herpes virus is unknown.
Native fish Platypus	Instream barriers (e.g., Gowangardie Weir and Broken River Weir) prevent fish movement and dispersal. Instream barriers can also increase the risk of platypus predation by forcing platypus to travel across land.	The GB CMA is seeking funding to remove Gowangardie Weir. Currently there is no funding or plans to address the other barriers in the Broken River and upper Broken Creek.
Native fish Macrophytes Macroinvertebrates Platypus	River regulation limits high natural flow events in the Broken River entering the upper Broken Creek. These high flow events are required to maintain the health of floodplain vegetation, promote fish movement, inundate floodplain wetlands and promote instream habitat diversity.	No action planned. Reinstating natural high flow events would inundate private property and assets.
Native fish Macroinvertebrates Platypus	Shallow water in weir pools heat up with high ambient temperatures reducing dissolved oxygen levels. Low stream velocities in weir pools and during low flow periods provide little opportunity for oxygenation through turbulence.	Continued delivery of low flows, especially during summer.

Increasing Knowledge

Monitoring

Current monitoring programs

VEFMAP was established in 2008 to evaluate the ecological response of fish, macroinvertebrates and vegetation to environmental flows. Previously the program surveyed fish, vegetation and macroinvertebrates in reaches 1 and 2 of the upper Broken Creek and reach 3 of the Broken River. VEFMAP monitoring in the upper Broken Creek ceased in 2016 and only annual fish surveys continue to be carried out in reach 3 of the Broken River. This was expanded in 2022 to include reach 1of the Broken River. Opportunistic fish surveys may be carried out in the upper Broken Creek through VEFMAP if resources allow.

Flow is monitored near real time on the Broken River downstream of Back Creek, at Caseys Weir, at Gowangardie Weir and at Orrvale. GMW monitors releases from Lake Nillahcootie. Near real time water quality (dissolved oxygen and temperature) monitoring occurs at Caseys and Gowangardie Weirs. Along the upper Broken Creek flow is monitored near real time at the Caseys Weir offtake and at Waggarandall Weir.

To help determine the impact of the summer blackwater event on upper Broken Creek water quality and the effectiveness of management responses, dissolved oxygen sensors were installed at Waggarandall and Flynns Weirs in late January 2022. The sensors were connected to DELWP's water monitoring network to provide the GB CMA with near real time dissolved oxygen data. The sensors are scheduled to be removed in June 2022. However, If funding allows the sensor at Waggarandall

Weir will be kept in place for an additional 12 months to better understand how dissolved oxygen levels change in response to flow and water temperature.

PIT (Passive Integrated Transponder) reader systems are installed on the Broken River at Caseys Weir and Lake Benalla. A total of 204 fish represented by three species (Murray cod, golden perch and carp) were PIT tagged in 2016 when the systems were installed. Movement of these and other tagged fish in the system can provide information on the movement ecology of native fish in the Broken River to inform:

- river restoration interventions;
- instream habitat protection and enhancement;
- refuge identification; and
- the planning and management of environmental flows.

Monitoring 2022-2023 environmental flow outcomes

In 2022-2023 VEFMAP will continue to conduct an annual fish population survey in reaches 1 and 3 of the Broken River. The survey collects data to help assess the influence of flow on the survival, recruitment, abundance and distribution of native fish over time.

Dependent upon available funding, the GB CMA will analyse data collected at the PIT reader systems on the Broken River at Caseys Weir and Lake Benalla in consultation with ARI. This will help improve our understanding of the movement ecology of native fish in the Broken River.

There is no funded monitoring planned for the upper Broken Creek to assess environmental flow outcomes. However, GB CMA and GMW staff will undertake field observations to inform environmental water planning and management.

The platypus population in Lake Benalla (on the Broken River) is monitored by volunteers through the Australia Platypus Monitoring Network (APMN). APMN is an innovative Citizen Science approach to monitoring platypus. Volunteers record platypus sightings at one or more sites using a standard visual survey method. This information is then analysed to see whether platypus activity is trending up or down or remaining steady over time.

Reporting

The first level of reporting is on the use of environmental entitlements. Weekly reporting advises environmental entitlement holders of progressive water use and on any adaptive water deployment decisions made.

The second level of reporting is on environmental outcomes achieved. Information on the use of environmental water, environmental outcomes recorded, and any knowledge gained will be reported to GB CMA partners and the board monthly and summarized in the next Broken River System seasonal watering proposal. VEFMAP also produces annual reports on the results of the program.

Knowledge Gaps and Limitations

The key knowledge gaps associated with the environmental water management in the Broken River system include:

- Information on the outcomes of environmental flows in both the upper Broken Creek and the Broken River (particularly in reaches 1 and 2).
- Accurate information on the channel capacity of the upper Broken Creek at a couple of locations downstream of Waggarandall Weir (reach 2).
- The relationship between flow and river height in reach 1 of the Broken River needs further confirmation to provide greater confidence that delivering fresh recommendations will not impact private landholders. Basic monitoring of the fresh delivered in autumn 2018 (relationship between flow and river height) and associated landholder engagement has helped to fill this knowledge gap.

- Integration of traditional ecological knowledge to improve the alignment of environmental watering with Traditional Owner biocultural values. It will be necessary to continue to work closely with Traditional Owners, and facilitate Traditional Owner led assessments of biocultural values to identify cultural priorities for watering such as support for food and medicinal plant species, or protection of culturally significant aquatic fauna. Investigation is also necessary to determine how best to facilitate ongoing involvement of Traditional Owners in order to identify and adequately consider indicators of these tangible biocultural values in environmental water planning, as well as better respond to intangible values such as the maintenance of connection to Country and the expression of cultural obligations to heal Country.

Risk Management

The risks associated with the delivery of the priority flow recommendations, the identified mitigation actions and the lead agency responsible for implementing the mitigation actions are listed in Table 13.

Table 13: Risk assessment of proposed water delivery

Legend for Tables:

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

No.	Risk category[1]	Risk description	L[2]	C[3]	Risk rating	Mitigation actions	Lead 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 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 *Notes: 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.	CMA CMA MDBA GMW VEWH

No.	Risk category[1]	Risk description	L[2]	C[3]	Risk rating	Mitigation actions	Lead for action
						River operators provide regular updates on flows, including through OAG meetings. Manage Water Holdings to maximise supply opportunities for all sites	
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. Has occurred in the upper Broken Creek below Caseys Weir offtake due to instream vegetation, which is also limiting flow capacity.	P	Mod	Medium	Review accounting and measurement processes to be used to ensure that techniques are agreed, and monitoring/measurement sites are operational. GMW to undertake additional gauging readings. Instream vegetation control in Broken Creek programmed for autumn (weather conditions permitting).	GMW GMW CMA
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.	U	Maj	Low	Ensure that deliveries are reported progressively throughout the event and are monitored against ordered volume. Ensure ordering and delivery procedures	CMA GMW GMW CMA VEWH CMA

No.	Risk category[1]	Risk description	L[2]	C[3]	Risk rating	Mitigation actions	Lead for action
		Notes: Planning watering actions also includes decisions around the carryover and trade of water as alternatives to current year water use decisions.				are kept up-to-date and adhered to. Ensure metering and reporting processes for temporary pump operations are suitable and effective	
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. *Notes: 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	CMA and GMW CMA

No.	Risk category[1]	Risk description	L[2]	C[3]	Risk rating	Mitigation actions	Lead for action
						avoid scheduled maintenance activities. Consider adding time contingencies to planned maintenance schedules to ensure works are completed prior to commencement of watering actions.	
8	Env	Failure of poorly maintained or vandalised delivery infrastructure results in planned/specified flows not being achieved, reducing the ability to achieve planned environmental outcomes.	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.* For privately owned assets, arrange approvals to use/operate assets and undertake pre-delivery inspections Report vandalism to police and review asset design to minimise opportunities for	Asset owner CMA Asset owner Asset owner PV

No.	Risk category[1]	Risk description	L[2]	C[3]	Risk rating	Mitigation actions	Lead for action
						interference or damage. Communicate failures to the CMA Initiate documentation of asset ownership and management arrangements in national parks.	
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.	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 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.	Asset owner Asset owner CMA (MDBA in Barmah Forest)

No.	Risk category[1]	Risk description	L[2]	C[3]	Risk rating	Mitigation actions	Lead for action
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	P	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	P	Min	Low	Seek to negotiate and formalise acceptable seasonal flow limits for river systems, with annual negotiation and management of release plans and reviews during the season as required.	VEWH DELWP CMA

No.	Risk category[1]	Risk description	L[2]	C[3]	Risk rating	Mitigation actions	Lead for action
		environmental improvements.					
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, where feasible and consistent with watering requirements. 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
13	Rep	Public land and/or access routes into	U	Mod	Low	Watering proposals to identify potential	CMA Land Mgr

No.	Risk category[1]	Risk description	L[2]	C[3]	Risk rating	Mitigation actions	Lead for action
		public land areas may be inundated by delivery of environmental water, leading to potential impacts on recreational opportunities for park users (e.g., access to boat ramps, fishing spots, firewood collection etc.).				impacts. Communication of planned events, access closures, alternative recreational opportunities and alternative access routes.	
14	Legal	Access routes into public land areas may be inundated by delivery of environmental water, leading to potential economic impacts on commercial operators who are unable to undertake activities (includes timber and firewood harvesting, apiarist, tourism operators).	U	Mod	Low	Communication and advice to commercial operators to alert them of environmental watering, via Land Manager as licensing authority.	Land mgr.
15	Serv Del	Access routes into public land areas may be inundated by delivery of environmental water, leading to potential impacts on land management and maintenance activities (e.g., fire mgmt. works)	U	Mod	Low	Early planning and communications of proposed actions with land manager to minimise likelihood of impacts, and scheduling of maintenance works outside of planned delivery periods.	CMA
16	Env	Environmental water deliveries result in low dissolved oxygen (DO)	U	Mod	Low	Where possible implement a full annual suite of flow	CMA

No.	Risk category[1]	Risk description	L[2]	C[3]	Risk rating	Mitigation actions	Lead for action
		levels, with adverse environmental impacts.				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 create hypoxic black water events	CMA CMA
17	Rep	Environmental water deliveries result in low DO levels, with adverse environmental impacts.	U	Mod	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	VEWH CMA CMA

No.	Risk category[1]	Risk description	L[2]	C[3]	Risk rating	Mitigation actions	Lead for action
						inform the local community of environmental water management activities and the underlying rationale. Communicate the mitigation actions/plans put in place to reduce risk of creating low DO events due to environmental water deliveries.	
18	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. Land managers or water corporation implement a risk-based monitoring program during environmental watering events, and where issues are identified, activate BGA response processes. Parks Victoria's BGA risk management plan for Northern Victoria Region that considers the potential risk of environmental water events is currently awaiting final approval. This plan outlines proactive and reactive monitoring and	CMA GMW Land mgr. GMW GMW

No.	Risk category[1]	Risk description	L[2]	C[3]	Risk rating	Mitigation actions	Lead for action
						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.	
19	Rep	Environmental water management activities may conflict with or not complement water based recreational objectives, leading to loss of community support for activities.	U	Mod	Low	Communicate benefits of environmental water management to the broader community and engage with recreational user peak bodies. Engage with local recreational user groups to inform them of environmental water management activities and the underlying rationale. Adjust events or actions to reduce/avoid impact where practical without reducing environmental outcomes.	VEWH CMA CMA Land mgr. VEWH

No.	Risk category[1]	Risk description	L[2]	C[3]	Risk rating	Mitigation actions	Lead for action
						Communicate alternate recreational opportunities. Enhance community understanding of water system operations and entitlement frameworks (water literacy).	
20	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
21	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.	CMA CMA

No.	Risk category[1]	Risk description	L[2]	C[3]	Risk rating	Mitigation actions	Lead for action
						Consider deferring deliveries until sufficient information is available to mitigate unacceptable risks. Implement adaptive management processes and undertake trials to collect data.	CMA
22	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.	CMA CMA
23	Legal	Environmental watering causes harm to identified cultural heritage	P	NA	NA	Work with Traditional Owners to ensure that the potential impact of environmental water deliveries on cultural heritage is understood and avoided or minimised and acceptable.	CMA

No.	Risk category[1]	Risk description	L[2]	C[3]	Risk rating	Mitigation actions	Lead for action
24	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 high after mitigation actions.	DELWP VEWH CMA
25	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	DELWP CMA or Land Mgr.

No.	Risk category[1]	Risk description	L[2]	C[3]	Risk rating	Mitigation actions	Lead for action
						removal program, waterlily spraying program, feral animal programs). Note: This risk is still rated as high after mitigation actions.	
26	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
27	Env	Ineffective planning 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
28	BC	River operators release water for flood mitigation which causes downstream flooding and debits those releases to environmental water accounts **Note that debits of releases to*	U	Mod	Low	Resolve appropriate water accounting treatment as part of the development of the Enhanced Environmental Water Deliveries SDL Adjustment Measures project (aka Hydrocues project).	VEWH DELWP MDBA

No.	Risk category[1]	Risk description	L[2]	C[3]	Risk rating	Mitigation actions	Lead for action
		environmental accounts is specific to Lake Hume and pre-releases from other storages could not be debited to environmental accounts				Refer to MDBA Environmental Water Management Group for development of suitable accounting arrangements.	
29	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
30	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.	U	Mod	Low	Communications to inform the community on the drivers/reasons for high flows in river systems, especially under dry scenarios	System operator CMA
31	Rep	Community concern over environmental releases under dry seasonal conditions may lead to a loss of support for environmental watering actions.	P	Mod	Medium	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	CMA VEWH

No.	Risk category[1]	Risk description	L[2]	C[3]	Risk rating	Mitigation actions	Lead for action
						frameworks (water literacy). Note: This risk is still rated as high after mitigation actions	
32	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 has been heightened as a result of the 2018/19 Menindee fish death events.	CMA
33	Env	Limited environmental deliveries may reduce opportunities to test ecological responses to environmental flows, impacting on effectiveness of research projects.	U	Mod	Low	Review monitoring program and adjust if possible. Reprioritise future flow targets.	CMA
34	Safety	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	CMA CMA CMA CMA

No.	Risk category[1]	Risk description	L[2]	C[3]	Risk rating	Mitigation actions	Lead for action
						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.	GMW
35	Env	Continuing dry conditions in the Broken system led to a Qualification of Rights in the Broken system, resulting in an inability to undertake planned watering events.	U	Mod	Low	Negotiate alternate water delivery opportunities and seek best possible environmental outcomes under the circumstances that prevail (e.g., including delivery to drought refuge sites).	CMA

Approval

I, Chris Cumming, the authorised representative of the agency shown below, approve the Seasonal Watering Proposal for the Broken River system 2022-23.

SIGNED FOR AND ON BEHALF OF Goulburn Broken Catchment Management Authority

Signature of authorised representative

Name of authorised representative

Chris Cumming (CEO)

Date: 13 April 2022

References

ARI (2022). Broken River fish population surveys 2022 – Field Survey Update (VEFMAP Stage 7). Report to the Goulburn Broken Catchment Management Authority by the Arthur Rylah Institute for Environmental Research.

Cottingham P., Stewardson M., Roberts J., Metzeling L., Humphries P., Hillman T. and Hannan G. (2001). Report of the Broken River scientific panel on the environmental condition and flows of the Broken River and Broken Creek. Report to Goulburn Broken Catchment Management Authority by Peter Cottingham & Associates.

Cottingham et al. (2012). Broken River Environmental Watering Project: site report. Report to the Goulburn Broken Catchment Management Authority and the G-MW Connections Project (previously NVIRP) by Peter Cottingham & Associates.

Cottingham P., Bond N., Boon P., Neal B., Nielsen D. Vietz G. and Woodman A. (2013a). Broken River environmental water plan: Issues Paper. Report to the Northern Victoria Irrigation Renewal Project and the Goulburn Broken Catchment Management Authority by Peter Cottingham & Associates.

Cottingham P., Bond N., Boon P., Nielsen D., Vietz G. and Neal B. (2013b). Broken River environmental watering plan. Report prepared for the Goulburn-Murray Water Connections Project and Goulburn Broken Catchment Management Authority by Peter Cottingham & Associates.

DSE (2009). Northern Region Sustainable Water Strategy. Department of Sustainability and Environment, Melbourne.

GBCMA (2005). Goulburn Broken Regional River Health Strategy 2005-2015. Goulburn Broken Catchment Management Authority, Shepparton.

Jacobs (2017). Upper Broken Creek Flows Study. Report to the Goulburn Broken Catchment Management Authority by Jacobs.

Serena M. and Williams G.A. (2010). Platypus population assessment and recommended management actions along Broken Creek. Report to Goulburn Broken Catchment Management Authority by the Australian Platypus Conservancy.

SKM (2007). Broken and Boosey Creeks Environmental Flow Determination Flow Recommendations. Report to the Goulburn Broken Catchment Management Authority by SKM.

Bloink C., Saddlier S., and Stevenson K. (2016). 2016 VEFMAP fish monitoring of the Goulburn River, Broken River and Broken Creek. Report prepared for the Goulburn Broken Catchment Management Authority by Ecology Australia.

Water Technology (2015). Goulburn Broken VEFMAP Vegetation Monitoring 2014. Report prepared for the Goulburn Broken Catchment Management Authority by Water Technology.

Tonkin, Z., Jones, M., O'Connor, J., Koster, W., Stamation, K., Kitchingman, A., Hackett, G., Dawson, D., Harris, A., Yen, J., Stuart, I., Clunie, P. and Lyon, J. (2019). VEFMAP Stage 6: Monitoring fish response to environmental flow delivery in northern Victorian rivers, 2018/19. Unpublished Client Report for Water and Catchments, Department of Environment, Land, Water and Planning. Arthur Rylah Institute for Environmental Research, Department of Environment, Land, Water and Planning, Heidelberg, Victoria.

Appendices

Appendix 1: Broken River ecological objectives and flow recommendations

The following table outlines the ecological objectives and associated flow components established for the Broken River in Cottingham et al (2013a). This table is be read in conjunction with the environmental flow recommendations outlined in the tables below this.

Ecosystem Attribute	Environmental or Ecological Values	Potential flow related threats	Flow-related ecological objectives	Reach	Flow Component	Mechanism	Season
Geomorphology	Geomorphic processes contribute to the availability and quality of in-channel and riparian habitat	• Reduced frequency of flow events capable of scouring sediments from pools • Reduced magnitude of spring and summer baseflow that allows encroachment by terrestrial vegetation • Longer than natural duration of low flow events, resulting in excessive deposition of fine materials. • Reduced frequency of flow events that maintain connectivity with riparian and floodplain habitats.	**G1**: Provide baseflow adequate to allow the persistence of aquatic macrophytes at the bank toe.	All	Base flow	Maintain wetted area to allow aquatic macrophytes to persist at the toe of the bank.	All
			G2: Provide baseflow to prevent terrestrial vegetation colonizing the stream bed.	All	Base flow	Maintain wetted area to halt the encroachment of terrestrial vegetation into the stream bed.	All
			G3: Maintain the rates of bed material movement to maintain bed diversity (sand and gravel bed).	All	Winter-spring freshes	Flows of sufficient magnitude to provide critical shear stress to periodically mobilize sand. Flows of sufficient magnitude to scour fine-grained (silt/clay) sediments from surficial coarse-grained sediments.	Win, Spr
			G4: Flows to turn over bed sediments in runs and scour around large wood.	All	Summer-autumn and winter-spring freshes	Flows of sufficient magnitude to provide critical shear stress to turnover bed sediments and scour around large wood.	All
			G5: Provide bench inundation to maintain bench form (and wet vegetation and promote the deposition/retention of organic matter).	All	Winter- spring freshes	Inundation of mid-level benches to a depth of >0.5 m above bench surface.	Win, Spr
			G6: Maintain connectivity between the channel, anabranches and wetlands.	All	Winter-spring bankfull and overbank flows	Flows of sufficient magnitude to inundate anabranches, wetlands and floodplain areas.	Win, Spr
	Intrinsic value of native vegetation	• Decreased	**R1**: Improve the longitudinal and lateral extent and condition of	All	Winter-spring freshes (Reach	Riparian vegetation (canopy layer as	Win, Spr

Ecosystem Attribute	Environmental or Ecological Values	Potential flow related threats	Flow-related ecological objectives	Reach	Flow Component	Mechanism	Season
Vegetation	Preservation of endangered EVCs Protection against bank/channel erosion and sediment suspension Interception of catchment-derived nutrients and sediments Provision of faunal habitat Moderation of in-stream temperatures	incidence of winter-spring flows, with impacts on freshes (especially in Reach 1) • Decreased incidence of bankfull and overbank flows (all Reaches) • Decrease in variability in flows (especially in Reach 3)	remnant native vegetation at the top of the bank and on the floodplain, with a focus on EVC 56: Floodplain Riparian Woodland.		1) (synonymous with bankfull flows in reaches 2 and 3) Winter-spring bankfull flows (Reaches 2 ad 3) Winter-spring overbank flows (Reaches 2 ad 3)	well as understorey) generally requires periodic inundation to maintain good condition of adults and to permit sexual recruitment of juveniles into the population.	
			W1: Maintain a mosaic of wetlands features, including maintenance of individual wetland/vegetation components within Floodplain Wetland Aggregate EVC.	All	Winter-spring freshes (based on wetland commence to fill data that only exists for Reach 3) Winter-spring bankfull flows	Wetland vegetation (generally requires alternating wet and dry cycles (involving periodic inundation and desiccation) to maintain a diversity of habitats and plant species, good condition of adults and to permit sexual recruitment of juveniles into the population.	Win, Spr
			W2: Maintain lateral linkages (hydrological and biological) between floodplain wetlands and main-stream channel of river.	All	Winter-spring overbank flows (to inundate floodplain more generally)	Floodplain rivers and their floodplains require lateral continuity to permit movement of adults and propagules among in-channel habitats, riparian habitats and floodplain wetlands for full ecological functioning.	Win, Spr

Ecosystem Attribute	Environmental or Ecological Values	Potential flow related threats	Flow-related ecological objectives	Reach	Flow Component	Mechanism	Season
					Winter-spring bankfull flows (all reaches)		
			IC5: Maintain in-channel native submerged and emergent vegetation.	2 and 3	Base flow (all year) Summer-autumn and winter-spring freshes	All-year base flows create conditions of permanent inundation that allow obligate submerged native plant taxa to establish and preclude invasion by flood-intolerant taxa. Freshes required to scour attached periphyton from plant surfaces. Freshes also provide a mosaic of habitats suitable for colonisation by different types of emergent water-dependent vegetation.	All
			IC6: Inundate benches, bars and low levels of the river bank to entrain organic matter and drive ecological processes such as carbon and nutrient cycling	All	Winter-spring freshes	Freshes required to entrain organic matter and from benches.	Win, Spr
Invertebrates	Invertebrates contribute to aquatic biodiversity, are important measures of river health and are integral components of food webs	• Reduced frequency of flow events capable of scouring sediments from pools • Reduced magnitude of	MI1: Maintain areas of riffles and runs.	1	Base flow (all year)	Flows of sufficient magnitude to inundate riffles and maintain runs.	All
			MI2: Maintain hydraulic habitat diversity to ensure that there is sufficient water to provide flowing and slackwater habitats within the channel	All	Spring-autumn baseflow	Flows of sufficient magnitude to maintain hydraulic habitat diversity, including slackwater.	Spr, Sum, Aut

Ecosystem Attribute	Environmental or Ecological Values	Potential flow related threats	Flow-related ecological objectives	Reach	Flow Component	Mechanism	Season
		spring and summer base flows that allows encroachment by terrestrial vegetation • Longer than natural duration of low flow events, resulting in excessive deposition of fine materials. • Reduced frequency of flow events that maintain connectivity with riparian and floodplain habitats.	**MI3**: Maintain habitat for macrophytes that provide crucial habitat for macroinvertebrates	All	Baseflow (all year) Summer-autumn and winter-spring freshes	As for IC4 and IC5.	Spr, Sum, Aut
			MI4: Scour fine sediment from the surface of the substrate to promote biofilm productivity	All	Winter-spring baseflow Winter-spring freshes	As for IC1 and IC4.	Win, Spr
			MI5: Provide floodplain connection for exchange of organic matter and fine sediment.	All	Winter-spring bankfull (connects to low level wetlands and other features) Winter-spring overbank flows (widespread floodplain connection)	As for R1	Win, Spr,
			MI6: Retain natural seasonality to ensure synchronicity of life cycle stages with appropriate flows.	All	Spring-autumn baseflow Winter-spring freshes Winter-spring bankfull flows Winter-spring overbank flows	Covered by all previous objectives.	All
Native fish	Native fish contribute to aquatic biodiversity, are key predator in aquatic food webs, valued for recreational fishing. In particular, Murray cod, Macquarie perch and	• Reduced magnitude of base flows that limit the area of habitat available for native	**NF1**: Provide low flows that maintain adequate habitat for native fish populations, particularly slack-water habitats and deep pools	All	Baseflow	Flow of sufficient magnitude to maintain low-flow (e.g. slackwater) habitat and pools.	Sum, Aut
			NF2: Provide flows sufficient to allow fish passage	All	Baseflow	Flow of sufficient depth across the	All

Ecosystem Attribute	Environmental or Ecological Values	Potential flow related threats	Flow-related ecological objectives	Reach	Flow Component	Mechanism	Season
	Silver perch are listed as vulnerable or threatened and are the focus of management objectives in the Goulburn-Broken Regional River Health Strategy.	fish. • Reduced magnitude of base flows that limits fish passage along river reaches. • Reduced frequency of spring flow pulses that serve as migration cues for some native fish. • Reduced frequency and magnitude of floodplain/wetland inundation events that provide habitat for some fish species, enhance riverine production and deliver food material back to the river.			Summer-autumn freshes	channel to allow fish passage.	
			NF3: Provide to water access to billabongs and flood-runners to provide additional habitat diversity and food sources that contribute to production.	All	Winter-spring bankfull flows	Flow of sufficient magnitude to inundate flood runners and floodplain wetlands.	Win, Spr
			NF4: Provide flow cues to stimulate movements	All	Variability	Flow events of sufficient magnitude to serve as breeding and migration cues.	All

Environmental flow recommendations for reach 1 outlined in Cottingham et al (2013a)

Objectives (habitat feature in parenthesis)	Main Flow Components	Flow Recommendation	Rationale
Recommendations for Low flow			
MI1, IC1 (riffles)	• Summer-autumn low flow	Minimum flow of 30 ML/d, or natural	• From HECRAS: water to cover riffles require >30 ML/d.
MI2 (slackwater)	• Spring-autumn low flow	Minimum flow of 30-100 ML/d, or natural (see accompanying rationale for expanded explanation) Absolute minimum of 10 ML/d (the desire is for this flow to persist along the length of the river)	• Meeting the needs of Reach 3 is assumed to meet the needs of Reach 1. See low flow objective MI2 for Reach 3 for full rationale.
IC2 (cobble and gravel bars)	• Winter-spring low flow	200 ML/d or natural	• Maintain minimum water level in stream at 10 cm over cobble and gravel bars. From HECRAS: ○ Winter-spring low flow requires >200 ML/d or natural.
NF1 (slackwater and pools)	• Summer-autumn low flow	As for MI2	• As for MI2.
MI3, MI6 (vegetation habitat and synchronicity)	• Low flow (all year)	As for MI1 and MI2.	• As for MI1 and MI2.

Objectives (habitat feature in parenthesis)	Main Flow Components	Flow Recommendation	Rationale
IC5 (vegetation habitat)	• Low flow (all year) • Summer and winter freshes	NA	• Reach 1 – minimal submerged vegetation – no specific recommendation for Reach 1. • Vegetation needs covered by recommendations for Reaches 2 and 3.
Recommendations for Freshes			
IC3 (vegetation encroachment on sand bars)	• Winter-spring freshes	270 ML/d. Frequency is 2 per year in dry years and 4 per year in average and wet years. Duration is 3 days in dry years, 6 days in average years and 9 days in wet years.	• Winter freshes to inundate low-lying sand bars. Based on HECRAS: ○ Reach 1 requires >270 ML/d,
G4 (scour around large wood)	• Summer-autumn and winter-spring freshes	400 ML/d. Frequency is 3 per year (all years), 2 in winter-spring and 1 in summer-autumn. Duration is 2 days in dry years, 5 days in average years and 8 days in wet years.	• As for G4 recommendations for Reach 3.

Objectives (habitat feature in parenthesis)	Main Flow Components	Flow Recommendation	Rationale
IC4 (biofilms)	• Summer-autumn and winter-spring freshes	500 ML/d. Frequency is 1 per year in dry years and 2 per year (1 in winter-spring and 1 in summer-autumn) in average and wet years. Duration is 2 days in dry years, 5 days in average years and 8 days in wet years.	• >0.6 m/s velocity for sloughing filamentous algae (based on Ryder et al. 2006). From HECRAS: ○ Reach 1 requires than 500 ML/d. Frequency is 1 per year in dry years and 2 per year (1 in winter-spring and 1 in summer-autumn) in average and wet years.
G3 (sand and gravel bed diversity)	• Winter-spring freshes	4,400 ML/d. Frequency is 1 in 3 years for average years and annually in wet years. Duration is 1 day in average years and 2 days in wet years.	• Removal of fine-grained sediments (silts/clays) from substrates in pools. Based on shear stress (30 N/m^2) required to overturn gravel substrate (particle size median) within majority of pools. From HECRAS: ○ Reach 1 requires 4,400 ML/d; mobilises sediments in 2 out of 3 pools.
IC1 (rifles)	• Winter-spring low flow	As for IC3	• Increasing the depth of low flow in winter by 0.2 m to stop excessive encroachment by terrestrial vegetation (see also objective G2). Based on HECRAS: ○ Reach 1 requires >175 ML/d.
G1, G2 (aquatic macrophytes, terrestrial encroachment)	• Low flow (all year)	As for IC3, IC4 and G3	• As for IC1 and IC2. Water level fluctuations of up to 0.2 m favours emergent aquatic macrophytes such as *Phragmites australis* (Deegan et al. 2007, Rogers and Ralph 2011) that can help to stabilise riverbanks.

Objectives (habitat feature in parenthesis)	Main Flow Components	Flow Recommendation	Rationale
G5 (bench inundation)	• Winter-spring freshes	As for G3.	• From HECRAS: ○ Reach 1 requires 4,000 ML/d (wets highest bench in the model and provide > 0.5 m depth over many benches to maintain bench form).
MI3, MI6, NF2 (invertebrate habitat, fish passage)	• Summer-autumn and winter-spring freshes	As for IC4.	• As for IC4.
NF4 (fish movement)	• Winter-spring freshes	As for G4, IC4, G3.	• Intention is for a rise in river levels of at least 0.2 m above antecedent winter low flow levels. • Magnitude covered by other objectives (e.g., G4, IC4, G3).
MI4 (biofilms)	• Winter-spring freshes	As for IC2 and IC3.	• As for IC2 and IC3.
IC6 (benches and bars)	• Winter-spring freshes	As for IC4	• As for G3 and G5.
Recommendations for Bankfull and Overbank flows			
W1 (wetlands)	• Winter-spring freshes (based on wetland commence to fill data for Reach 3)	4,000-9,000 ML/d**#** Frequency for events above 6,000 ML/d is 1 in 10 years for	• Governed by the W1 recommendation for Reach 3. • Connection occurs in average and wet years, as flows of these magnitudes do not occur in dry years. Frequency of events from 4,000-6,000 ML/d is as for objectives G3 and G5. Frequency for events of 6,000-9,000 ML/d is 1 in 10 years for average years and 1 in 2 years for wet years.

Objectives (habitat feature in parenthesis)	Main Flow Components	Flow Recommendation	Rationale
		average years and 1 in 2 years for wet years. Duration is 1 day in average years and wet years.	• #Flows for Reach 1 are described as freshes due to bankfull flows being unrealistic in the confined morphology.
R1 (riparian zone)	• Winter-spring freshes (approaching bankfull flows)	As for W1.	• River Red Gum used as a surrogate for EVC 56. Both bankfull and overbank flows are recommended to ensure the needs of the understorey are met in addition to RRG. • From HECRAS: ○ Reach 1: freshes of 4,000 – 7,000 ML/d; • Flows of this magnitude would not be expected in dry years. Frequency is 1 in 10 years for average years and 1 in 2 years in wet years. Timing: spring if possible.
G6, W2, IC1, IC2, IC3, MI5, MI6, NF3	• Winter-spring freshes (approaching bankfull)	As for W1 and R1.	• Freshes approaching bankfull as for W1 and R1.

Environmental flow recommendations for reach 2 outlined in Cottingham et al (2013a)

Objectives (habitat feature in parenthesis)	Main Flow Components	Flow Recommendation	Rationale
Recommendations for Low flow			
MI1 (riffles)	• Summer-autumn low flow	Minimum flow of 40 ML/d, or natural	• From HECRAS: water to maintain runs: ○ Reach 2 requires 40 ML/d or natural
MI2 (slackwater)	• Spring-autumn low flow	Minimum flow of 30-100 ML/d, or natural (see accompanying rationale for expanded explanation) Absolute minimum of 15 ML/d (flow to persist along the length of the river)	• Meeting the needs of Reach 3 is assumed to meet the needs of Reach 2. See low flow objective MI2 in Reach 3 for full rationale.
IC5 (vegetation habitat)	• Low flow (all year)	Minimum flow of 100 ML/d, or natural	• Low flow with 0.5 m depth are based on the watering needs of *Vallisnaria* (Bowen 2006, Roberts and Marston 2011, Rogers and Ralph 2011). The watering needs of emergent vegetation (e.g., Phragmites) are expected to be catered for by the low flow for *Vallisnaria* and freshes as defined for other objectives. • Maintain 0.5 m depth in runs. From HECRAS: ○ Reach 2 requires 100 ML/d, or natural
IC3 (vegetation encroachment on sand bars)	• Low flow (all year)	As for MI1 and MI2	• As for MI1, MI2.

Objectives (habitat feature in parenthesis)	Main Flow Components	Flow Recommendation	Rationale
NF1 (slackwater and pools)	• Summer-autumn low flow	As for MI2	• As for MI2.
NF2 (fish passage)	• Low flow (all year)	As for MI1	• Intent is 0.4 m over the shallowest point in the longitudinal profile. From HECRAS: ○ Reach 2 requires 40 ML/d.
MI3, MI6 (invertebrate habitat)	• Low flow (all year)	As for MI1 and MI2.	• As for MI1 and MI2.
G1, G2 (aquatic macrophytes, terrestrial encroachment)	• Low flow (all year)	As for MI1, MI2 and IC5	• As for MI1, MI2 and IC5.
Recommendations for Freshes			
G4 (scour around large wood)	• Summer-autumn and winter-spring freshes	400 ML/d. Frequency is 3 per year (all years), 2 in winter-spring and 1 in summer-autumn. Duration is 3 days in dry years, and 5 days in average and wet years.	• Shear stress for removing fines from sediments in runs equal to 2 N/m² (based on shear stress required to mobilise sandy bed sediments in runs). From HECRAS: ○ Reach 2 requires 400 ML/d.

Objectives (habitat feature in parenthesis)	Main Flow Components	Flow Recommendation	Rationale
IC3 (vegetation encroachment on sand bars)	• Winter-spring freshes	430 ML/d. Frequency is 3 per year (all years). Duration is 3 days in dry years, and 5 days in average and wet years.	• Winter freshes. Based on HECRAS: ○ Reach 2 - features are indistinct from HECRAS, so adopt Reach 3 requirements. ○ Reach 3 requires 430 ML/d.
G3 (sand and gravel bed diversity)	• Winter-spring freshes	2,600 ML/d. Frequency is 1 in 2 years for dry years, 3 per year in average years and 5 per year in wet years. Duration is 1 day in dry years, and 2 days in average years and 4 days in wet years.	• Removal of fine-grained sediments (silts/clays) from substrates in pools. Based on shear stress (30 N/m^2) required to overturn gravel substrate (particle size median) within majority of pools. From HECRAS: ○ Reach 2 requires 2,600 ML/d.
IC4 (biofilms)	• Winter-spring freshes	4,300 ML/d. Frequency is 1 in 10 years for dry years, 2 per year for average years and 4 per year in wet years.	• This will require a combination of (i) sloughing algae (freshes) and (ii) turning over cobbles (bankfull, addressed by R1, W1). • >0.6 m/s velocity for sloughing (based on Ryder et al. 2006). Based on HECRAS: ○ Reach 2 requires 4,300 ML/d. Frequency is as for objective G5.

Objectives (habitat feature in parenthesis)	Main Flow Components	Flow Recommendation	Rationale

G5 (bench inundation)	• Winter-spring freshes	4,500 ML/d.
		
		Frequency is 1 in 10 years for dry years, 2 per year for average years and 4 per year in wet years.
		
		Duration is 1 day in dry years, and 2 days in average years and 3 days in wet years.
			• From HECRAS:
			  ○ Reach 2 requires 4,500 ML/d. Frequency is 1 in 10 years for dry years, 2 per year for average years and 4 per year in wet years.
			  ○ Duration 1-2 days, with appropriate rates of rise and fall.

IC6 (benches and bars)	• Winter-spring freshes	As for IC4	• As for G3 and G5.
NF4 (fish movement)	• Winter-spring freshes	As for G4, IC4, G3.	• Intention is for a rise in river levels of at least 20 cm above antecedent winter low flow levels. • Magnitude as for G3, IC4.
MI4 (biofilms)	• Winter-spring freshes	As for IC3.	• As for IC3.
MI3, MI6, NF2 (invertebrate habitat, fish passage)	• Summer and winter freshes	As for IC2, IC3 and IC4.	• As for IC2, IC3 and IC4.
Recommendations for Bankfull and Overbank flows			

Objectives (habitat feature in parenthesis)	Main Flow Components	Flow Recommendation	Rationale
R1 (riparian zone)	• Winter-spring freshes (approaching bankfull flows)	16,000 ML/d. Frequency is 1 in 5 years for average years and 8 in 10 years for wet years. Duration is 1 day for average and wet years.	• River Red Gum used as a surrogate for EVC 56. Both bankfull and overbank flows are recommended to ensure the needs of the understorey are met in addition to RRG. • From HECRAS: ○ Reach 2: bankfull of 16,000 ML/d; • Bankfull and overbank flows would not be expected in dry years. • Note: it is recognised that the proposition to actively manage the flows required for this recommendation will not been accepted due to Victorian policy of not inundating private land. However, it is stated here to provide completeness in terms of recommendations for maintaining or improving the conditions of ecosystem assets and values associated with the Broken River. As the current flow regime has had little effect on the natural frequency of events of this magnitude, it is expected that this recommendation will be met without active management.
W1 (wetlands)	• Winter-spring freshes (based on wetland commence to fill data for Reach 3)	As for R1	• As for R1
G6, W2, IC1, IC2, IC3, MI5, MI6, NF3	• Winter-spring freshes (approaching bankfull)	As for W1 and R1.	• Freshes approaching bankfull as for W1 and R1.

Environmental flow recommendations for reach 3 outlined in Cottingham et al (2013a)

Objectives (habitat feature in parenthesis)	Main Flow Components	Flow Recommendation	Rationale
Recommendations for Low flow			
MI1 (riffles)	• Summer-autumn low flow	40 ML/d, or natural.	• From HECRAS: water to maintain runs: ○ Reach 2 requires 40 ML/d or natural
MI2 (slackwater)	• Spring-autumn low flow	30-100 ML/d, or natural. Absolute minimum of 15 ML/d.	• Slackwater habitat is best defined here as depth <0.5 m and velocity <0.05 m/s (Vietz et al. 2013). Vietz et al. (2013) show the area of slackwater available in Reach 3 at different discharges (as a proportion of bankfull – approx. 20,000 ML/d). Slackwater habitat area is at its minimum at approximately 800 ML/d and at its maximum at 30-40 ML/d. • Dec-Apr daily flows are very similar for dry and average years (the difference between the 2 scenarios is more pronounced in winter-spring). The Dec-Apr p20 value (i.e., flows are above 100ML/day for <20% of the time) for dry and average years is approximately 100 ML/d (± approximately 20 ML/d). • The nature of discharge-slackwater habitat area is such that as discharge increases or decreases, a 50% reduction in slackwater habitat occurs outside the range of 8-120ML/day (a discharge of 8-10 ML/d represents a 33% reduction; 15 ML/d represents a 20% reduction). • Operate within range of 30-100 ML/d, or natural with an absolute minimum of 15 ML/d.

Objectives (habitat feature in parenthesis)	Main Flow Components	Flow Recommendation	Rationale
			• Flows outside of this range are restricted to short periods (e.g., as freshes), with appropriate rates of rise and fall).
IC5 (vegetation habitat)	• Low flow (all year)	80 ML/d, or natural.	• Low flow with 0.5 m depth are based on the watering needs of *Vallisnaria* (Bowen 2006, Roberts and Marston 2011). The watering needs of emergent vegetation (e.g., Phragmites) are expected to be catered for by the low flow for *Vallisnaria* and freshes as defined for other objectives. • Maintain 0.5 m depth in runs. From HECRAS: ○ Reach 3 requires 80 ML/d, or natural
IC3: (vegetation encroachment on sand bars)	• Low flow (all year)	As for MI1 and MI2	• As for MI1, MI2.
NF1 (slackwater and pools)	• Summer-autumn low flow	As for MI2	• As for MI2.
NF2 (fish passage)	• Low flow (all year)	As for MI1	• Intent is 0.4 m over the shallowest point in the longitudinal profile. From HECRAS: ○ Reach 2 requires 40 ML/d.
MI3, MI6 (invertebrate habitat)	• Low flow (all year)	As for MI1 and MI2.	• As for MI1 and MI2.
G1, G2 (aquatic macrophytes, terrestrial encroachment)	• Low flow (all year)	As for MI1, MI2 and IC5	• As for MI1, MI2 and IC5.

Objectives (habitat feature in parenthesis)	Main Flow Components	Flow Recommendation	Rationale
Recommendations for Freshes			
G4 (scour around large wood)	• Summer and winter freshes	400 ML/d. Frequency is 3-4 per year (dry, wet and average years).	• Shear stress for removing fines from sediments in runs equal to 2 N/m² (based on shear stress required to mobilise sandy bed sediments in runs). From HECRAS: ○ Reach 3 requires 400 ML/d. Frequency is 3-4 per year (dry, wet and average years).
IC3 (vegetation encroachment on sand bars)	• Winter-spring freshes	430 ML/d. Frequency is 3 per year (dry, wet and average years). Duration is 3 days in dry years, 5 days in average years and 6 days in wet years.	• Winter freshes. Based on HECRAS: ○ Reach 3 requires 430 ML/d.
G3 (sand and gravel bed diversity)	• Winter-spring freshes	1,000 ML/d. Frequency is 2 per year for dry years, 4 per year in average and wet years. Duration is 2 days in dry years, 4 days in average years and 6 days in wet years.	• Removal of fine-grained sediments (silts/clays) from substrates in pools. Based on shear stress (30 N/m²) required to overturn gravel substrate (particle size median) within majority of pools. From HECRAS: ○ Reach 3 requires 1,000 ML/d.

Objectives (habitat feature in parenthesis)	Main Flow Components	Flow Recommendation	Rationale
IC4 (biofilms)	• Winter-spring freshes	4,300 ML/d. Frequency is 1 in 10 years for dry years, 2 per year for average years and 4 per year in wet years. Duration is 1 days in dry years, 2 days in average years and 3 days in wet years.	• This will require a combination of (i) sloughing algae (freshes) and (ii) turning over cobbles (bankfull, addressed by R1, W1). • >0.6 m/s velocity for sloughing (based on Ryder et al. 2006). Based on HECRAS: ○ Reach 2 requires 4,300 ML/d. Frequency is as for objective G5.
G5 (bench inundation)	• Winter-spring freshes	4,500 ML/d Frequency and duration as for IC4.	• From HECRAS: ○ Reach 2 requires 4,500 ML/d.
IC6 (benches and bars)	• Winter-spring freshes	As for IC4.	• As for G3 and IC4.
NF4 (fish movement)	• Winter-spring freshes	As for G4, IC4, G3.	• Intention is for a rise in river levels of at least 20 cm above antecedent winter low flow levels. • Magnitude as for G3, IC4.
MI4 (biofilms)	• Winter-spring freshes	As for IC3.	• As for IC3.

Objectives (habitat feature in parenthesis)	Main Flow Components	Flow Recommendation	Rationale
MI3, MI6, NF2 (invertebrate habitat, fish passage)	• Summer and winter freshes	As for IC2, IC3 and IC4.	• As for IC2, IC3 and IC4.
Recommendations for Bankfull and Overbank flows			
R1 (riparian)	• Winter-spring freshes (approaching bankfull flows)	20,000 ML/d Frequency is 1 in 10 years in average years and 7 out of 10 years in wet years. Duration is 1 day for both average and wet years.	• River Red Gum used as a surrogate for EVC 56. Both bankfull and overbank flows are recommended to ensure the needs of the understorey are met in addition to RRG. • From HECRAS: ○ Reach 3: bankfull of 20,000 ML/d; • Bankfull and overbank flows would not be expected in dry years. • Note: it is recognised that the proposition to actively manage the flows required for this recommendation will not been accepted due to Victorian policy of not inundating private land. However, it is stated here to provide completeness in terms of recommendations for maintaining or improving the conditions of ecosystem assets and values associated with the Broken River. As the current flow regime has had little effect on the natural frequency of events of this magnitude, it is expected that this recommendation will be met without active management.
W1 (wetlands)	• Winter-spring freshes (based on wetland commence	As for R1	• As for R1

Objectives (habitat feature in parenthesis)	Main Flow Components	Flow Recommendation	Rationale
	to fill data for Reach 3)		
G6, W2, IC1, IC2, IC3, MI5, MI6, NF3	• Winter-spring freshes (approaching bankfull)	As for W1 and R1.	• Freshes approaching bankfull as for W1 and R1.

Appendix 2: Upper Broken Creek ecological objectives and flow recommendations

The following tables outlines the ecological objectives and associated flow components established for the upper Broken Creek in Jacobs (2017). These tables are to be read in conjunction with the environmental flow recommendations outlined in the table below this.

Reach 1 ecological objectives and associated flow components

Objective	Number	Function	Flow component	Timing	Expected response
Geomorphology					
Maintain channel form and where possible provide flows sufficient to mobilise sediments and maintain pools	G1.1	Minimise further sedimentation of pools	High flows	Winter/spring	Higher flows help to prevent excessive accumulation of sediment. However, flows alone are unlikely to be sufficient to significantly scour existing pools. Management of weir pools and selective excavation may be required to create deeper habitat pools.
Periodically engage distributary channels	G1.2	Engage channels to maintain drainage network	Bankfull / overbank flows		Overbank flows will spill into distributary channels helping to preserve the distributary drainage network and provide occasional inundation of off channel habitats.
Vegetation					
Promote the germination and recruitment of river red gums within the riparian zone.	V1.1	Provide soil moisture to promote germination Reduce grazing pressure on seedlings	Bankfull / overbank flows	Winter/spring	Germination and recruitment of river red gum requires overbank flows and exclusion of stock.
Maintain and promote in channel biodiversity (e.g. *Triglochin* spp)	V1.2	Scouring and maintenance of pools to provide habitat for *Triglochin* spp.	High flows	Winter/spring	*Triglochin* can survive periods of dry by persistence, is reliant on in channel pools. Flows need to be sufficient to mobilise sediment and maintain pools.
Minimise the spread of Cumbungi within the channel	V1.3	Scouring of pools	High flows	Winter/spring	Minimising the spread of Cumbungi is conditional on either prolonged drying or prolonged inundation at sufficient depth to prevent further growth.
Reduce the encroachment of riparian species (e.g. water couch) into the river channel	V1.4	Deep inundation of benches to limit growth of terrestrial species	High flows	Winter/spring	Deep inundation drowns species that prefer shallow / damp conditions.
Water Quality					
Maintain water quality	W1.1	Maintain pools during periods of low flow	Freshes	All year	Water quality should be maintained at levels that are not detrimental to aquatic biota (DO >6 mg/L)
Fish					
Maintain conditions for self-sustaining populations of small-bodied native fish	F1.1	Maintain aquatic habitat for all native fish species	Low flow	All year	Sustained populations of river blackfish, smelt, Murray River rainbowfish, Carp Gudgeons and stocked native species (Murray cod and golden perch).
Maintain conditions for survival of large-bodied native fish	F1.2	Provide migration cue and longitudinal passage for small and large-bodied native fish	High flow	Winter/Spring	Maintain population resilience to local fluctuations in abundance. Recolonization after drought conditions.
Platypus					
Maintain platypus population and support successful breeding and juvenile dispersal	P1.1	Maintain access to habitat and sufficient food resources	Low flows	All year	Low flows maintain access to habitat & provide conditions suitable for macroinvertebrates as a food source.
	P1.2	Provide opportunities for dispersal of juveniles	Freshes	Autumn	Increased flow promotes juvenile dispersal.
	P1.3	Avoid deliberate high flows in nesting season	Avoid high flow	Late spring/summer	Minimise unintended inundation of nests.
Macroinvertebrates					
Maintain self-sustaining populations of macroinvertebrates	M1.1	Maintain perennial nature of the reach. Maintain aquatic habitat including vegetation and wood.	Low flows	All year	Sustained populations of Decapoda species (shrimps).

Reach 2 ecological objectives and associated flow components

Objective	Number	Function	Flow component	Timing	Expected response
Geomorphology					
Maintain channel form and where possible provide flows sufficient to mobilise sediments and maintain channel capacity for water delivery to Moodies Swamp	G2.1	Flush accumulated sediment	High flows	Winter/spring	Higher flows help to prevent excessive accumulation of sediment. However, flows alone are unlikely to be sufficient to significantly scour existing pools. Management of weir pools and selective excavation may be required to create deeper habitat pools.
Periodically engage distributary channels	G2.2	Engage channels to maintain drainage network	Bankfull / overbank flows		Overbank flows will spill into distributary channels helping to preserve the distributary drainage network and provide occasional inundation of off channel habitats (e.g. Moodies Swamp).
Vegetation					
Promote the germination and recruitment of river red gums within the riparian zone.	V2.1	Provide soil moisture to promote germination Reduce grazing pressure on seedlings	High flows	Winter/spring	Germination and recruitment of river red gum requires overbank flows and exclusion of stock.
Maintain and promote in channel biodiversity (e.g. *Triglochin* spp)	V2.2	Scouring and maintenance of pools to provide habitat for *Triglochin* spp.	High flows	Winter/spring	*Triglochin* can survive periods of dry by persistence is reliant on in channel pools. Flows need to be sufficient to mobilise sediment and maintain pools.
Minimise the spread of Cumbungi within the channel	V2.3	Scouring of pools	High flows	Winter/spring	Minimising the spread of Cumbungi is conditional on either prolonged drying or prolonged inundation at sufficient depth to prevent further growth.
Reduce the encroachment of riparian species (e.g. water couch) into the river channel	V2.4	Deep inundation of benches to limit growth of terrestrial species	High flows	Winter/spring	Deep inundation drowns species that prefer shallow / damp conditions.
Fish					
Maintain conditions for self-sustaining populations of small-bodied native fish	F1.1	Maintain refuge aquatic habitat for all native fish species	Low flow	All year	Sustained populations of small-bodied fish and opportunistic presence of larger bodied species – cease to flows may occur but permanent pool habitat expected to remain (e.g. McLaughlin's weir).
Maintain conditions for survival / refuge habitat for large-bodied native fish - opportunistic	F1.2	Provide migration cue and longitudinal passage for small and large-bodied native fish	High flows	Winter/Spring	Maintain population resilience to local fluctuations in abundance. Recolonisation after sustained drought conditions.
	F2.3	Inundate in-channel benches and low-lying fringing vegetation	High flows	Winter/Spring	Access to spawning habitat and food resources.
Platypus					
Maintain refuge / critical feeding habitat for platypus	P2.1	Maintain pools to serve as drought refuges and assist successful downstream dispersal of juveniles	High flows	Winter/spring	High flows provide connection that fills pools serving as drought refuges and providing foraging habitat for dispersing juveniles - cease to flows may occur but permanent pool habitat expected to remain.
Macroinvertebrates					
Maintain self-sustaining populations of macroinvertebrates	M2.1	Maintain refuge aquatic habitat including vegetation and large woody debris	Low flows	All year	Sustained populations of Decapoda species (shrimps) - cease to flows may occur but permanent pool habitat expected to remain.

Reach 3 ecological objectives and associated flow components

Objective	Number	Function	Flow component	Timing	Expected response
Geomorphology					
Transition towards a series of linear wetlands	G3.1	Sediment from upstream reaches will continue to accumulate in Reach 3	NA	NA	Accumulated sediment will result in further channel constriction. Even high flows are not competent to flush accumulated material through this reach. High flows will cause inundation of low lying areas.
Vegetation					
Promote the germination and recruitment of river red gums within the riparian zone.	V3.1	Provide soil moisture to promote germination Reduce grazing pressure on seedlings	Bankfull / overbank flows	Winter/spring	Germination and recruitment of river red gum requires overbank flows and exclusion of stock.
Promote the development of a vegetation community consistent with regional wetland EVCs	V3.2	Allow occasional inundation to a variety of depths to support wetland plant biota	Freshes/High flows	Autumn / winter / spring	Germination and recruitment of wetland plant species.
Fish					
Maintain conditions for opportunistic colonisation of small-bodied native fish	F3.1	Maintain opportunistic aquatic habitat for small-bodied native fish	Freshes/High flows	Autumn / winter / spring	Opportunistic presence of small-bodied native fish e.g. smelt, Murray River rainbowfish, Carp Gudgeons.
	F3.2	Provide migration cues and longitudinal passage for small and large-bodied native fish	High flow	Winter/Spring	Maintain population resilience to local fluctuations in abundance; Recolonization after sustained drought conditions.
Platypus					
Maintain opportunities for downstream dispersal by juveniles	P3.1	Longitudinal connection that provides opportunities for downstream dispersal of juveniles	Freshes/High flows	Autumn/early Winter	High flows provide connection that fills refuge pools and promotes successful downstream dispersal.
Macroinvertebrates					
Maintain self-sustaining populations of macroinvertebrates tolerant of cease to flow periods	M3.1	Allow occasional inundation to a variety of depths to support macroinvertebrate biota tolerant of cease to flow periods	Freshes/High flows	Winter/spring	Diverse macroinvertebrate community tolerant of cease to flow periods

The following table outlines ecological objectives and flow recommendations in the upper Broken Creek Flows Study (Jacobs 2017).

Stream		Broken Creek		Reach 1	Casey's Weir to Waggarandall Weir
Compliance point		Waggarandall Weir		Gauge No.	404239 (Waggarandall Weir)
Season	Component	Volume*	Frequency	Duration	Objective
Summer / autumn (Dec-May)	Cease-to-flow	Not recommended			
	Low flow	5 ML/d (dry) 10 ML/d (avg) 10 ML/d (wet)	All season		M1.1, F1.1, P1.1
	Fresh	20 ML/d (avg) 50 ML/d (wet)	Once per year in average and wet climate years. Timed to coincide with filling Moodies Swamp. A proportion of the flow could be diverted to fill Moodies Swamp with the remainder passing to downstream reaches. Not required/expected in dry climate years.	Within the period Apr – Jun for as long as required to fill Moodies Swamp	W1.1, P1.2
	High flows	No specific recommendation but allowed to occur in response to local catchment runoff.			
Winter / spring (June-Nov)	Cease-to-flow	Not recommended			
	Low flow	10 ML/d (dry) 15 ML/d (avg) 20 ML/d (wet)	All season		M1.1, F1.1, P1.1
	Fresh	15 ML/d (dry) 20 ML/d (avg) 50 ML/d (wet)	Once per year in dry, average and wet climate years. A proportion of the flow could be diverted to fill Moodies Swamp, if a top up was required, with the remainder passing to downstream reaches.	2 weeks within the period Sep – Oct to coincide with topping up Moodies Swamp and growing period for vegetation. Duration could be longer if required to deliver water to Moodies Swamp	F1.2, P1.2, V1.2, V1.3, V1.4
	High flow / bankfull	Up to 200 ML/d	Only expected in very wet climate years once every 5 to 10 years in response to local catchment runoff. Local runoff could be augmented with transfers via Casey's Weir.	Determined by duration of local runoff. If augmentation from Casey's weir is provided, then 1-2 days.	G1.1, G1.2
	Overbank	No specific recommendation but allowed to occur in response to local catchment runoff.			

Appendix 3: Ecological Condition Supporting Information

Native fish community

VEFMAP fish population survey results between 2008 and 2022 indicate the Broken River supports a diverse and abundant native fish community. Fish species recorded include Murray cod (*Macullachella peelii*), Golden perch (*Macquaria ambigua*), Silver perch (*Bidyanus bidyanus*) River blackfish (*Gadopsis marmoratus*), Trout cod (*Macullachella macquarensis*), Australian smelt (*Retropinna semoni*) and Murray-Darling rainbowfish (*Melanotaenis fluviatilis*). The results indicate Murray cod (*Macullachella peelii*) and Murray-Darling rainbowfish are the most abundant fish followed by the introduced carp. The results also indicate fish habitat is good, with an abundance of woody debris, macrophytes, overhanging terrestrial vegetation, pools and flow variability (Bloink et al 2016).

In autumn 2021, a Broken River VEFMAP fish population survey was undertaken in reach 2 and 3. The key results included:

- Approximately half the number of Murray Cod were captured compared to the 2020 survey. Most fish captured were juvenile fish. However, consistent with previous survey results, Murray Cod were the dominant species captured, with multiple size classes present.
- No young of year Murray Cod were captured. Reduced detection due to turbid water may have contributed to this result. However, low flows last year may have impacted the body condition of Murray Cod and their reproductive output. The higher flows experience this season are expected to improve the body condition of Murray Cod and improve their reproductive output next spring.
- Golden perch were present in relatively high numbers, particularly upstream of Gowangardie Weir. These are most likely stocked fish.
- No Silver Perch were captured. They have been captured in the three previous surveys.
- Small-bodied species such as Murray-Darling rainbowfish and Carp Gudgeon were evenly distributed across sites and relatively abundant.

The upper Broken Creek VEFMAP fish survey results between 2008 and 2016 indicated the fish community was stable and dominated by small-bodied fish including the native Murray-Darling rainbowfish and the introduced Eastern Gambusia. Large bodied native fish were dominated by the introduced carp, goldfish and redfin. Large bodied native fish including River blackfish, Golden perch and Murray cod are found in small numbers. The shallow habitat and relatively static hydrological regime of the upper Broken Creek, particularly in reach 1, is considered favourable for introduced species such as carp, Eastern Gambusia and goldfish. However, there is an abundance of woody debris, macrophytes and overhanging terrestrial vegetation along sections of the creek which provide good fish habitat (Bloink et al 2016).

In autumn 2020, an upper Broken Creek VEFMAP fish population survey was undertaken at two sites in reach 1. The key results included:

- River blackfish were captured from one site and low numbers of Murray-Darling rainbowfish were captured at both sites. The small number native fish captured was likely a reflection of the low flows in 2019-20.

Vegetation

Upper Broken Creek and Broken River VEFMAP vegetation monitoring results between 2008 and 2014 indicated riparian vegetation cover and diversity was reasonably stable. Mature old River Red Gums and Grey Box dominated the overstorey. However, past and present grazing pressure had inhibited the recruitment of native shrubs and herbs reducing the structural complexity and diversity of the vegetation and introduced grasses dominate the ground layer in some areas. The main channels of the Broken River and upper Broken Creek supported extensive areas of native macrophytes. Eelgrass, Common reed and Water Ribbons were the dominate Broken River macrophytes and Tall Spike-sedge and Knotweed were the dominate Broken Creek macrophytes (Water Technology 2015).

Cabomba (*Cabomba caroliniana*) is a weed of national significance and was first identified in Lake Benalla (Broken River in reach 2) in the 1990s. The lake was drawn down in 2009, 2010 and 2018 to dry and kill the plants. This has been moderately successful in controlling the cover and abundance of Cabomba. In January 2020 small infestations of Cabomba were again recorded in the lake which expanded significantly by January 2021. The GB CMA in partnership with the Benalla Rural City Council and GMW drew the lake down in mid-February 2021 to control the Cabomba infestation. The lake was surveyed in February 2022 and no Cabomba was recorded. This indicates the drawdown in January 2021 was successful in controlling the infestation and it is hoped another drawdown will not be required for several years.

Small satellite populations of Cabomba exist in the upper Broken Creek downstream of Caseys Weir and in the Broken River upstream of Caseys Weir (including Stockyard Creek). The GB CMA in partnership with GMW and Benalla Rural City Council will look for opportunities to control these infestations when flow conditions allow.