Australian Government

Commonwealth Environmental Water

ENVIRONMENTAL WATER DELIVERY

Gunbower Forest

FEBRUARY 2012 V1.0

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Flood waters in the forest – Gunbower Forest flood, September 2010
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Gunbower Forest
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Environmental Water Delivery: Gunbower Forest

Increased volumes of environmental water are now becoming available in the Murray-Darling Basin and this will allow a larger and broader program of environmental watering. It is particularly important that managers of environmental water seek regular input and suggestions from the community as to how we can achieve the best possible approach. As part of the consultation process for Commonwealth environmental water we are seeking information on:

1. community views of environmental assets and the health of these assets
2. the prioritisation of environmental water use
3. partnership arrangements for the management of environmental water
4. possible arrangements for the monitoring, evaluation and reporting (MER) of environmental water use.

This document has been prepared to provide information on the environmental assets and potential environmental water use in Gunbower Forest. As the first version of the document, it is intended to provide a starting point for discussions on environmental water use. As such, suggestions and feedback are encouraged and will be used to inform planning for environmental water use and future iterations of the document.

Gunbower Forest supports significant conservation values including numerous threatened native flora and fauna, as well as bird species protected under international migratory bird agreements. In addition, Gunbower Forest has been recognised as a wetland of international significance under the Ramsar Convention. Potential water-use options for Gunbower Forest include the provision of inflows during winter, spring and summer to maintain riparian vegetation and aquatic habitat for fish, invertebrates, turtles and birds by filling wetlands and watercourses throughout the forest. Provision of passing flows at Koondrook Weir will also maintain fish passage at Gunbower Creek weirs and provide aquatic habitat in lower Gunbower Creek to support local fish populations.

A key aim in undertaking this work was to prepare scalable water-use strategies that maximise the efficiency of water use and anticipate different climatic circumstances. Operational opportunities and constraints have been identified and delivery options prepared. This has been done in a manner that will assist the community and environmental water managers in considering the issues and developing multi-year water-use plans.

The work has been undertaken by consultants on behalf of the Commonwealth Department of Sustainability, Environment, Water, Population and Communities. Previously prepared work has been drawn upon and discussions have occurred with organisations such as the North Central Catchment Management Authority and the Murray-Darling Basin Authority.

Management of environmental water will be an adaptive process. There will always be areas of potential improvement. Comments and suggestions, including on possible partnership arrangements, are very welcome and can be provided directly to ewater@environment.gov.au. Further information about Commonwealth environmental water can be found at www.environment.gov.au/ewater.

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Abbreviations

AHD	Australian height datum
BoM	Bureau of Meteorology
CAMBA	China-Australia Migratory Bird Agreement
CEWH	Commonwealth Environmental Water Holder
CMA	Catchment management authority
CSIRO	Commonwealth Scientific and Industrial Research Organisation
DECCW	NSW Department of Environment, Climate Change and Water
DSE	Victorian Department of Sustainability and Environment
EPBC	*Environment Protection and Biodiversity Conservation Act 1999* (Cwlth)
EVC	Ecological vegetation class (Victoria)
EWAG	Environmental Water Advisory Group
FFG	*Flora and Fauna Guarantee Act 1988* (Victoria)
GL	Gigalitre (1,000,000,000 litres)
G-MW	Goulburn-Murray Water
ICC	Integrated Coordinating Committee
JAMBA	Japan-Australia Migratory Bird Agreement
MDB	Murray-Darling Basin
MDBA	Murray-Darling Basin Authority
MDBC	Murray-Darling Basin Commission
ML	Megalitre (1,000,000 litres)
MLD EWAG	Murray Lower Darling Environmental Water Advisory Group
MSM Bigmod	Murray Simulation Model—Big Model. (The Murray-Darling Basin Authority's existing river simulation model. A custom designed water resources planning model of the main stem of the Murray River system.)
NCCMA	North Central Catchment Management Authority
NOW	NSW Office of Water
NRSWS	Northern Region Sustainable Water Strategy
NVIRP	Northern Victoria Irrigation Renewal Project
OEH	NSW Office of Environment and Heritage
SEWPaC	Australian Government Department of Sustainability, Environment, Water, Population and Communities
SRA	Sustainable Rivers Audit
TLM	The Living Murray
VEWH	Victorian Environmental Water Holder

PART 1:
Management aims

1. Overview

1.1 Scope and purpose

The purpose of this document is to provide scalable strategies for environmental water use based on the environmental requirements of selected assets. This document outlines the processes and mechanisms that will enable water use strategies to be implemented in the context of river operations and delivery arrangements, water trading and governance, constraints and opportunities. The document proposes large-scale water use options for the application of environmental water.

To maximise the systems' benefit, three scales of watering objectives are expressed:

- water management area (individual wetland features/sites within an asset)
- asset objectives (related to different water resource scenarios)
- broader river system objectives across and between assets.

These objectives provide the basis for the proposed water use strategies and the premise for which the delivery document has been developed.

Assets and potential watering options have been identified for regions across the Basin. This work has been undertaken in three steps:

- Existing information for selected environmental assets has been collated to establish asset profiles, which include information on hydrological requirements and the management arrangements necessary to deliver water to meet ecological objectives for individual assets.
- Water-use options have been developed for each asset to meet watering objectives under a range of volume scenarios. Use of environmental water will aim to maximise environmental outcomes at multiple assets, where possible. Water use options will provide an "event ready" basis for the use of environmental water. Options are expected to be integrated into a five-year water delivery program.
- Processes and mechanisms that are required to operationalise the environmental water use strategies are documented and include such things as:
  - delivery arrangements and operating procedures
  - water delivery accounting methods that are either currently in operation at each asset, which could be applied for accurate accounting of inflow, return flows and water 'consumption'

- decision triggers for selecting any combination of water-use options
- approvals and legal mechanisms for delivery and indicative costs for implementation.

This document is for the delivery of water in Gunbower Creek and Gunbower Forest (Figure 1). It should be noted that the Gunbower Forest lies within the larger water planning area of the Central Murray Floodplains (Yarrawonga to the Wakool Junction). The actions and activities identified within this document must be considered in conjunction with the environmental water delivery documents for the Koondrook-Perricoota Forest, Barmah-Millewa Forest and the Edward-Wakool system, and the hydrologically connected assets such as the Lower Goulburn floodplain, Broken Creek and the Campaspe River.

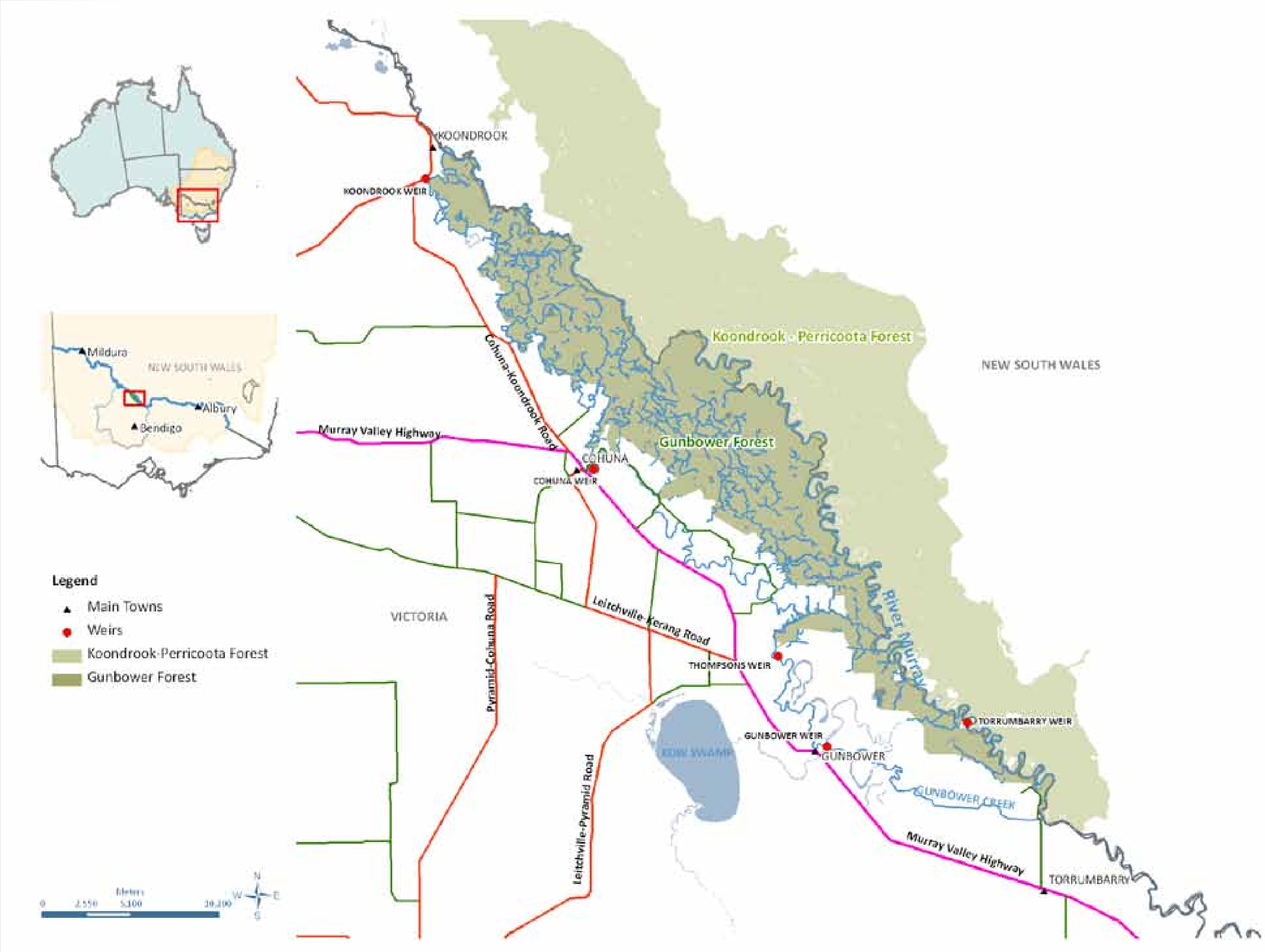


Figure 1: Gunbower Forest and Koondrook-Perricoota Forest (MDBA 2010a).

1.2 Catchment and river system overview

Gunbower Forest is part of the Murray River catchment and is located downstream of Torrumbarry Weir, between the Campaspe and Loddon Rivers.

The Murray River originates on the western slopes of the Great Dividing Range, south of Thredbo, and flows in a westerly direction. Major tributaries within the upper slopes include the Swampy Plain River, Corryong, Cudgewa, Limestone and Burrowye creeks. Further west the Mitta Mitta and Kiewa rivers rise and flow north to join the Murray River near Lake Hume. Below Lake Hume the major tributaries of the Murray River include Billabong Creek, the Murrumbidgee River and the Darling River, which enter from the north, and the Ovens, Goulburn, Campaspe and Loddon Rivers, which enter from the south. Other tributaries that are encompassed by the Upper and Central Murray region include Broken Creek, which meets the Murray River near Barmah, and the Edward and Wakool Rivers, which enter the river just downstream of Swan Hill.

Topography varies widely across the region, from rugged alpine terrain with high altitude plateaus and steep narrow valleys, grading to undulating foothill slopes, flat to gently undulating country in the Riverina plains, and low relief floodplains (CSIRO 2008).

The major flow regulating structures on the Murray, upstream of Gunbower Forest, are Dartmouth Dam (3,856,000 ML), Hume Dam (3,005,000 ML), Yarrawonga Weir (118,000 ML), Lake Eildon (3,334,000 ML), Lake Eppalock (312,000 ML) and Torrumbarry Weir (37,000 ML).

1.3 Overview of river operating environment

Gunbower Forest is a floodplain system of the Murray River located in northern Victoria on the southern bank of the river between Torrumbarry and Koondrook (Figure 2). The northern bank of the river is occupied by the Koondrook-Perricoota Forest.

Flows in the Murray River under regulated flow conditions are sourced from Hume Reservoir and Lake Eildon. Hume Dam releases water to Yarrawonga Weir and to the Murray River downstream.

The principal sources of water for Gunbower Forest are:

- Murray River, upstream of Albury where water is stored in Hume and Dartmouth Reservoirs
- Ovens River, which provides unregulated river inflows to the Murray River below Hume Reservoir
- Broken Creek, which provides irrigation drainage and some winter run-off
- Goulburn River, where water is stored in Lake Eildon
- Campaspe River, where water is stored in Lake Eppalock.

Hume, Eildon and Eppalock reservoirs are managed primarily to capture inflows in winter and spring, and release water (as regulated flow) to supply consumers. Irrigated agriculture is the largest consumer of water which is delivered via several main routes:

- Murray River flow below Hume Reservoir is diverted from Yarrawonga Weir to the north via Mulwala Canal and to the south via Yarrawonga Main Channel. Yarrawonga Weir also supplies water down the Murray River, although deliveries are subject to the constraints of the Barmah Choke.
- Murray River flow is also diverted at Torrumbarry Weir (via National Channel), which is located directly upstream of Gunbower Forest.
- Goulburn River flow below Lake Eildon is diverted to the Waranga Basin and via the East Goulburn Main Channel at Goulburn Weir.

1.4 Overview of forest operating environment

Torrumbarry Weir, which is located directly upstream of the Gunbower Forest, provides a weir pool for diversion along the National Channel into the Torrumbarry Irrigation Area. The National Channel also supplies Gunbower Creek, which forms the southern border of the forest and is an anabranch of the Murray River. Gunbower Creek has several weirs to allow diversion for irrigation, stock and domestic and town water supply, as well as regulators which can release water to the forest (Figure 2).

Works within Gunbower Forest, currently being designed and constructed under The Living Murray program, can be split into two groups:

- The Hipwell Road package of works
- Lower Landscape Structures.

These works will allow water to be released to the mid forest and lower forest, inundating wetland and forest areas. It is forecast that these works will come into operation in 2013.

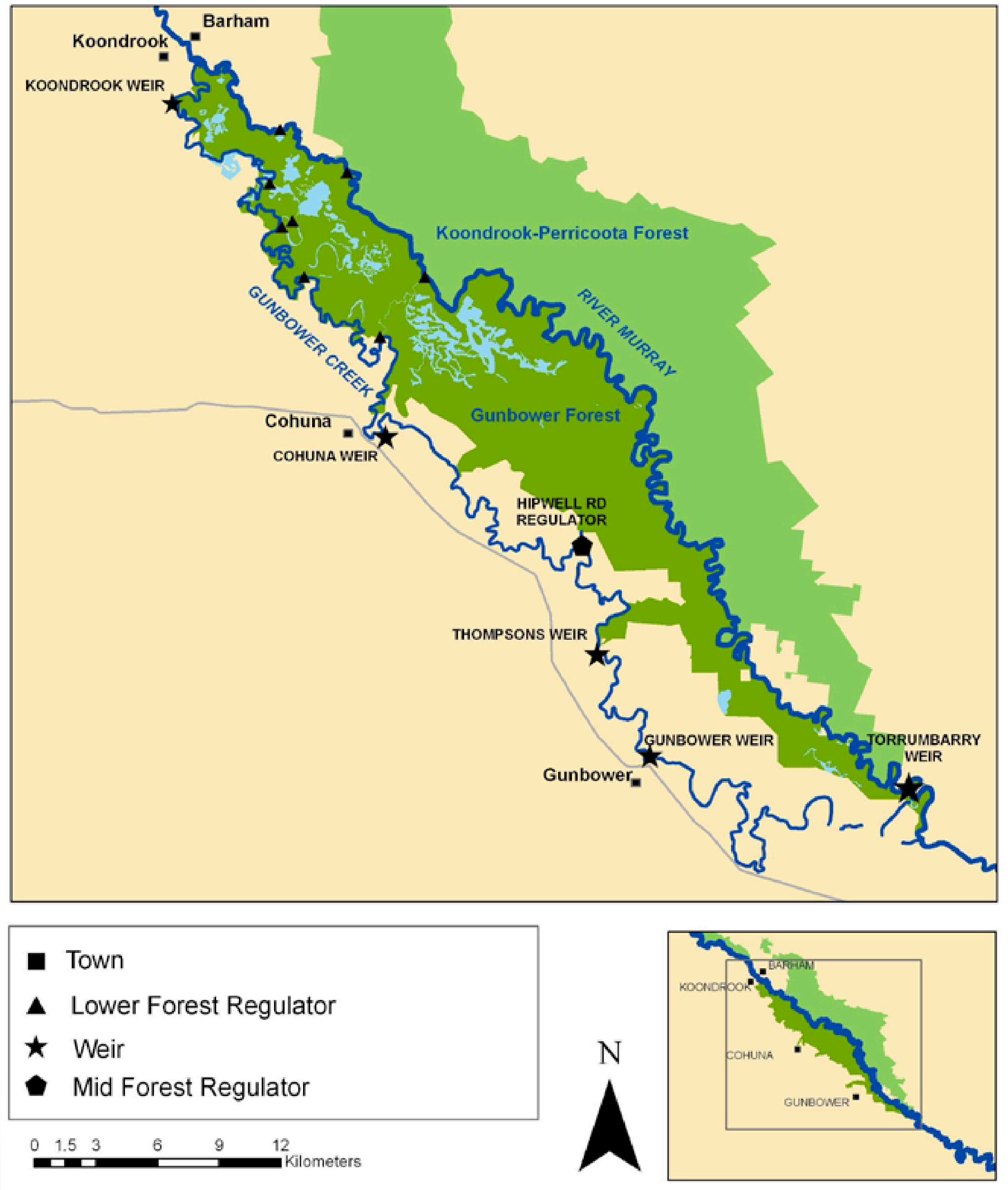


Figure 2: Water management overview.

The lower forest regulators manage water in localised wetland areas (Figure 3). Water can be introduced to the Little Reedy and Little Gunbower complexes from the Yarran Creek and Little Gunbower regulators. Regulators on Reedy Lagoon and Black Swamp allow targeted filling of these wetlands from Gunbower Creek. Inflows from the lower forest regulators are complemented by inflows from the Hipwell Road mid-forest regulator.

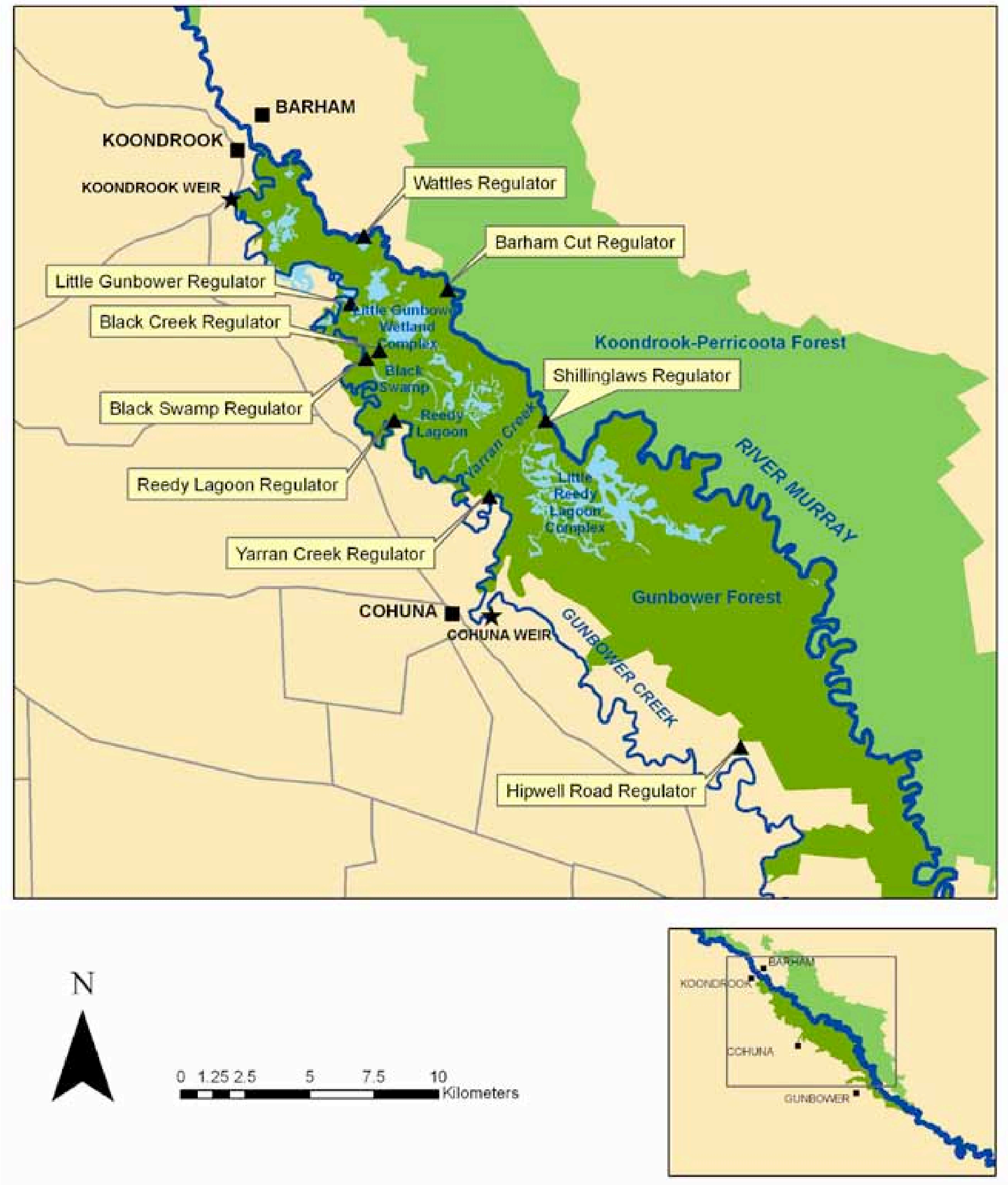


Figure 3: Lower landscape and Murray River effluent regulators.

Forest regulator functions and capacities are shown in Table 1. Two regulators facilitate the drainage of water to and from the forest to the Murray River and can be operated in managed and natural flood events. Shillinglaws regulator (located on the Yarran Creek effluent) is the largest and drains the mid-forest and Little Reedy Lagoon areas. Barham Cut regulator influences smaller areas connecting into the Little Gunbower wetland complex and is effective in managing wetland flooding in the lower forest at low water levels.

Wattles regulator was constructed in the 1970s to facilitate drainage of the forest for logging activities. This regulator was decommissioned in 2005-06 and has no operational capacity.

Table 1: Forest regulator functions.

Regulator	Primary functions	Maximum capacity (ML/d)
Mid-forest regulator		
Hipwell Road	Introduces water from Gunbower Creek to river red gum forest and wetlands of mid-forest and lower-forest areas.	1,650
Lower-forest regulators		
Yarran Creek regulator	Introduces water from Gunbower Creek to Little Reedy complex and provides some flow to lower-forest areas.	920 ML/d initially, but reducing to 120 ML/d as forest fills with water
Reedy Lagoon regulator	Introduces water from Gunbower Creek to Reedy Lagoon permanent wetland.	330
Black Swamp regulator	Introduces water from Gunbower Creek to the Black Swamp permanent wetland.	93
Black Creek regulator	Drains water from Black Swamp Permanent Wetland to the Little Gunbower wetland complex.	–
Little Gunbower regulator	Introduces water from Gunbower Creek to the Little Gunbower wetland complex.	350
Murray River effluent regulators		
Shillinglaws regulator	Facilitates drainage of the Little Reedy Wetland Complex to the Murray River. Can facilitate small inflows from the Murray River: approximately 100 ML/d at river discharge of 20,000 ML/d, increasing at higher flows.	~ 2,500 ML/d (for Murray River flows downstream of Torrumbarry of 30,000 ML/d)
Barham Cut regulator	Helps retain water within the forest in the Little Gunbower wetland complex. Facilitates drainage of the Little Gunbower Wetland Complex to the Murray River. Allows natural inflows from the Murray River.	~ 100 ML/d (for Murray River flows downstream of Torrumbarry of 30,000 ML/d)
The Wattles regulator	Decommissioned regulator with sill matching to the level of the adjacent natural river levee.	–

(Source: MDBA 2011)

2. Ecological values, processes and objectives

2.1 Ecological values

2.1.1 Overview of assets

Gunbower Forest covers 19,450 hectares and when combined with the contiguous Koondrook-Perricoota Forest of 34,546 hectares, forms the second-largest river red gum forest in Australia. Black box and grey box woodlands occupy the higher-elevation fringes of the forest and wetlands are present in the lower, more frequently inundated areas.

The forest extends from the National Channel (Gunbower Creek) in the south to the junction of Gunbower Creek with the Murray River at Koondrook in the north (Figure 1). The forest occurs principally on Gunbower Island, which is formed between Gunbower Creek (a regulated anabranch) and the Murray River. Gunbower Creek is managed as a component of the Torrumbarry Irrigation District to supply water from the Murray River via the National Channel. Gunbower Forest is bounded by agricultural land, roads and sections of Gunbower Creek on its south-western side.

The forest is confined to a width of less than two kilometres or so at the upstream end between the National Channel and the Cohuna Channel. Near Cohuna the forest widens out significantly to a maximum width of about eight kilometres before progressively narrowing towards the northern end.

Flooding of Gunbower Forest is determined by the height (i.e. flows) of the Murray River below Torrumbarry Weir. Flows at Torrumbarry comprise inflows from the Murray River downstream of Barmah, and the Goulburn and Campaspe Rivers (URS 2001).

The forest is located within two local government areas, Gannawarra Shire and Campaspe Shire, and lies within the North Central Catchment Management Authority region.

Gunbower Forest is a combination of state forest, national park and reserve. The state forest portion (8,843 hectares) is managed under the Mid-Murray Forest Management Plan by Victoria's Department of Sustainability and Environment Land and Fire division. The Gunbower National Park, managed by Parks Victoria, was proclaimed in June 2010 and encompasses 8,892 hectares.

The banks of the Murray River are designated as Murray River Reserve. The land occupies 1,666 hectares and is managed by Parks Victoria. The riparian zone along Gunbower Creek is a Public Land Water Frontage Reserve and is managed by DSE (Land and Fire). Surrounding the forest to the south-west is predominantly private agricultural land supporting mainly stock grazing and dairying enterprises.

2.1.2 Conservation value

Gunbower Forest is a wetland of international significance recognised under the Ramsar Convention. The forest is public land that is managed for conservation and timber harvesting (state forest) or conservation, recreation and education (National Park, Murray River Reserve, education area and public land water frontage). Gunbower Forest is part of the Gunbower-Koondrook-Perricoota Forest Icon Site under the TLM program of the Murray-Darling Basin Authority.

More than 450 species of native flora and 299 species of native fauna have been recorded at Gunbower Forest. Of these, 20 flora species and 66 fauna species have conservation significance under Victorian policy or statutory instruments or the *Environment Protection and Biodiversity Conservation Act 1999* (Cwlth) (Appendix 1). Nine plant species and thirteen animal species are vulnerable or endangered under the EPBC Act.

Seven bird species listed under the Japan-Australia Migratory Bird Agreement (JAMBA) and ten species listed under the China-Australia Migratory Bird Agreement (CAMBA) have been recorded. Seven of these species are common to both agreements (Appendix 1).

Gunbower Forest includes the following vegetation communities of conservation significance:

- The river red gum grassy woodland ecological community is listed under the *Flora and Fauna Guarantee Act 1988* (Vic).
- Grey box grassy woodlands and derived native grasslands of south-eastern Australia were listed (EPBC Act) as endangered ecological communities on 1 April 2010.

The forest contains a highly diverse wetland system covering 10,000 hectares. It is important feeding, nesting and breeding habitat for more than 22 waterbird species, and is one of only two known breeding sites for intermediate egrets in Victoria. The site is listed on the Register of the National Estate for its value as a waterfowl breeding area (MDBA 2011a,b).

Gunbower Creek contains critical habitat for the trout cod (*Maccullochella macquariensis)* listed as endangered under the EPBC Act. Other notable records include crimson spotted rainbowfish, which are uncommon in the mid-Murray region (Rehwinkel & Sharpe 2010).

2.1.3 Ecosystem structure

Forest and wetlands

The lowest elevations of Gunbower Forest support permanent and semi-permanent wetlands where water typically persists between inflow events (Figure 4). These provide valuable habitat for a variety of wetland plants, fish, frogs, waterfowl and other aquatic species. The wetlands can support colonial waterbird breeding and their deep pools can provide a refuge during drought (URS 2001).

The permanent wetlands of Reedy Lagoon and Black Swamp are located in the lower forest near Gunbower Creek (Figure 3). These wetlands provide reliable nesting habitat for small populations of waterbirds and support native fish, frogs and aquatic meadow vegetation. As permanent aquatic habitat, the wetlands represent a refuge for aquatic biota that can recolonise the forest when flooding returns after extreme drought conditions.

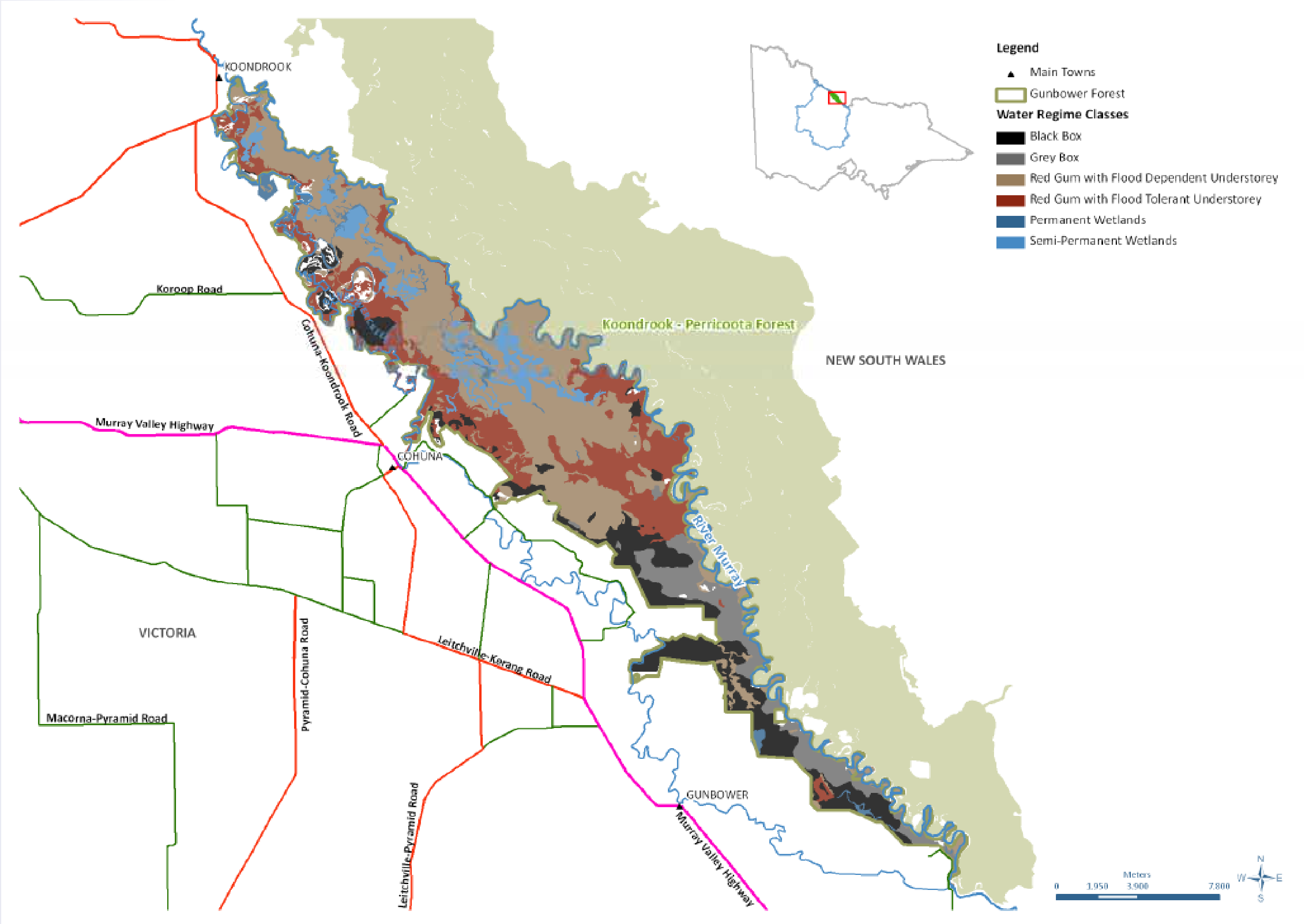


Figure 4: Water regime classes (MDBA 2010a).

The semi-permanent wetland complexes of the Little Reedy Lagoon and Little Gunbower have historically provided reliable waterbird breeding habitat for a range of colonial nesting species including the intermediate egret. The wetlands also provide reliable aquatic habitat for fish, frogs, tortoises and yabbies which can disperse to other parts of the forest when floods provide additional aquatic habitat. The wetlands have historically been filled with almost annual inflows from the Murray River in winter and spring. The depleted flow regime in the river has resulted in the contraction of the wetlands, encroachment by river red gum, less frequent and smaller waterbird breeding events and the loss of resident populations of aquatic fauna.

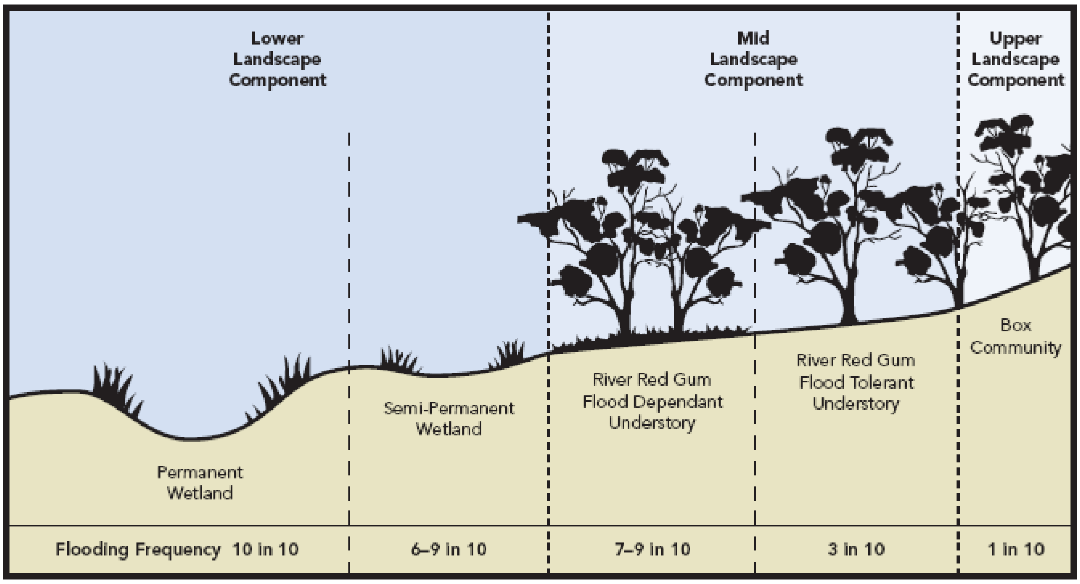


Figure 5: Schematic plan of water management areas in Gunbower Forest (MDBA 2010b).

Higher ground surrounding the wetlands supports river red gum forest with a flood-dependent understorey. This plant community is adapted to almost annual flooding for periods of several months. The understorey comprises aquatic plant species such as Warrego summer grass, terete culm-sedge, milfoil and giant rush, during floods, with some annuals and flood-tolerant tussock plants appearing when flood water recedes. When flooded, this community provides fish nursery areas, feeding and breeding areas for colonial waterbirds such as egrets and waterfowl, as well as breeding sites for several frog species (URS 2001).

At higher elevations river red gum woodland with flood-tolerant understorey becomes dominant, followed by black box in infrequently flooded areas and grey box on the highest elevations where flooding is rare.

Effluents and watercourses occur throughout the forest. These have pools along their length and support emergent macrophytes, provide fish habitat and support large trees along their edges, which provide a nesting and roosting resource for waterbirds.

Gunbower Creek

Gunbower Creek provides a permanent habitat for native fish, invertebrates and turtles. The creek system includes flowing reaches, pools, wooded riparian zones, dense beds of aquatic macrophytes, backwaters and lagoons.

Gunbower Creek provides habitat for 12 species of native fish, and provides important regional populations of trout cod, freshwater catfish and Murray River rainbow fish. The creek sustains these fish through the presence of permanent aquatic habitat; a combination of pool, backwaters and flowing reaches; and diverse and generally healthy riparian marshy and woody vegetation.

Environmental watering of Gunbower Creek aims to provide fauna with more extensive habitat, greater mobility to migrate between the river, forest and creek, breeding cues related to flood events and access to nursery habitat for juvenile fish. These outcomes will be facilitated by the delivery of water to Gunbower Forest via Gunbower Creek, the construction of fishways on the environmental flow regulators and the provision of a passing flow at Koondrook Weir.

The lower reach of Gunbower Creek, below Koondrook Weir, does not normally flow and fills only via backwater effects from the Murray River as river flows start to rise. The inundation of accumulated organic matter with little through-flow or mixing can create conditions for blackwater events. The provision of an environmental flow at Koondrook Weir, together with a future fishway, potentially provides a permanent downstream flow connection between the creek.

2.1.4 Current condition

Over the past decade, drier conditions have resulted in a shift towards more terrestrial vegetation types across Gunbower Forest. This change is most pronounced in the understorey species composition of the river red gum communities, which are exhibiting significant loss of plant diversity and weed invasion (Australian Ecosystems 2008).

The extent of river red gum with flood-dependant understorey has decreased and is now restricted to a narrow zone around the wetlands (Ecological Associates 2003). This has resulted in an increase in the area of river red gum with flood-tolerant understorey, which now extends into the lower parts of the forest and is encroaching on formerly open wetlands (Australian Ecosystems 2008). At higher elevations, river red gums are being replaced by the less flood-dependant black box woodlands (Ecological Associates 2003). Monitoring of canopy condition since 2005 has recorded an ongoing decline in eucalypt canopy health (Australian Ecosystems 2008).

Lack of inundation has also impacted on floodplain productivity and access to food and habitat by native fauna, leading to a decline in the populations of these species and their resilience to additional stressors. This is most evident for colonial waterbird populations where the extended periods between large flow events that supports large-scale breeding opportunities poses a key threat to the viability of existing populations (MDBA 2011).

Ecological processes required to sustain native fish populations, such as connectivity to the floodplain for breeding and recruitment, have also been hindered (Ecological Associates 2010). Regulated flows in Gunbower Creek are providing limited opportunity for breeding in the larger-bodied native fish as demonstrated by the low population numbers detected through surveys of the creek (Rehwinkel & Sharpe 2010).

Regular inundation events of various sizes are required to maintain healthy and functioning ecological communities in Gunbower Forest. Regulation of the Murray River has resulted in a reduction in the magnitude, frequency and duration of flow events as shown in Table 2.

Table 2: The effects of regulation on flows in the Murray River at Torrumbarry Weir

Murray River flow	Average duration[1] (months/event)		Frequency[2] (Number of events/100 years)	
ML/d	Natural	Historic regulated	Natural	Historic regulated
≥13,000	6.2	3.9	97	55
>15,200	6.0	3.7	98	53
>18,300	5.5	3.6	94	46
>25,200	4.4	3.2	91	37
>27,800	4.2	3.1	84	34
>36,000	3.4	2.6	68	27
>46,000	2.8	2.6	42	8
>56,500	1.8	2.5	11	2

Source: Ecological Associates (2003).

Note: Data is based on modelled monthly flows from MDBA—Monthly Simulation Model for flows between 1891 and 1990.

1 Duration is the average number of months per event that monthly flow exceeds the threshold values shown in ML/d column.

2 Frequency is the number of years, in the 100 years modelled, in which one or more months had flows exceeding the threshold values shown in ML/d column.

Large flow events that exceed 36,000 ML/d result in overbank flows and widespread inundation of the river red gum areas. The frequency of these flows has fallen significantly (reduction of 58 per cent) since regulation, although the duration of these events is much the same.

The frequency of intermediate-sized flows (18,000–30,000 ML/d) since regulation has not declined as dramatically, however the event duration has been reduced by almost 50 per cent. For example, prior to regulation, flows greater than 18,000 ML/d had a duration of five and half months, these same flow events now have a duration of only three and half months (Ecological Associates 2003).

For the smaller flow events (18,000 ML/d), both the frequency and duration have been more than halved under regulation. The duration of these smaller flow events is critical in ensuring that the lower flows into the forest are sustained for long enough to fill permanent and semi-permanent wetlands in the forest (Ecological Associates 2003).

An extensive and prolonged blackwater event occurred when Gunbower Forest was naturally flooded between September 2010 and February 2011. Blackwater developed when organic matter that had accumulated on the floodplain was inundated and decomposed. Anoxic conditions resulted in localised fish kills in Gunbower Creek (M Tranter (North Central CMA), pers. comm., December 2010). The situation was exacerbated by the already high organic loads and low oxygen concentrations of water entering the system from the Murray River due to floodplain inundation in Barmah Forest and elsewhere. It is likely that severe blackwater conditions occurred because of the long period between the 2010–11 floods and the last comparable flood in 1996, during which organic matter accumulated on the floodplain and contributing catchments. In addition, inundation occurred during the warmer months (spring and summer).

The frequency and duration of high flows under historic regulated conditions are insufficient to meet the water requirements of the forest ecosystem. The significant alteration to the water regime of Gunbower Forest has caused:

- the loss of permanent wetlands and a large reduction in the extent of other wetland types
- a reduction in the frequency and size of breeding events of colonial nesting waterbirds
- a reduction in the temporarily flooded wetland and forest habitats, and a decline in the number and diversity of associated flora and fauna
- a decline in the condition of river red gum, black box and grey box woodlands
- reduced connectivity between the river and floodplain forest limiting access to food and habitat for aquatic fauna
- increased severity of blackwater events
- reduced opportunities for recreational activities associated with aquatic areas e.g. canoeing
- reduced opportunities for cultural activities associated with flooding events.

2.2 Ecological objectives

The objectives for watering options in Gunbower Forest are to:

- maintain aquatic habitat and facilitate fish breeding, dispersal and migration in Gunbower Creek
- facilitate fish movement to and from Gunbower Creek, Gunbower Forest and the Murray River
- maintain the health and habitat values of creek habitat and riparian vegetation within Gunbower Forest
- restore the plant community structure and diversity of wetlands, forest and woodlands
- promote successful breeding events by waterbirds, fish and other fauna by providing seasonal inundation in wetland and forest habitats
- minimise blackwater risks
- promote natural carbon exchange (cycle) between the river and floodplain.

The objectives are presented for four water availability scenarios: extreme dry, dry, median and wet.

The scenarios refer primarily to the amount of environmental water that is available in a given year, thus determining the environmental watering objectives. When water is scarce it will be used to maintain ecosystem viability, and when water is abundant it will be used to promote long-term ecosystem health and increase the size and resilience of populations.

The water availability scenarios are not entirely independent of ambient flow conditions. It is most likely that Murray River flows will be very low when environmental water reserves are low and that high flow events will already be occurring in years when environmental water reserves are high. Environmental water is used most efficiently when the flow thresholds of the target assets are close to the ambient river flow. The objectives have been set to make efficient use of the ambient flows that are likely to occur in the four scenarios.

In extreme dry and dry conditions there will be little or no flow entering Gunbower Forest from the Murray River. The priority for water management will therefore be to maintain aquatic refuges in the permanent wetlands (Reedy Lagoon and Black Swamp) and the semi-permanent wetlands (Little Reedy Lagoon complex and Little Gunbower complex). Maintaining water in these wetlands will help maintain vegetation structure and avoid the colonisation of drying wetland beds by river red gum. However, in some very dry years it may be appropriate to allow a drying period to occur in the forest.

Gunbower Creek is an important habitat for native fish. In extreme dry and dry scenarios it will be important to support refuge populations of native fish by providing sufficient through-flow to maintain fish passage at the weirs along the creek, to maintain flowing water reaches and to provide some variability in water level. Flows will also enable small-scale bird-breeding events to maintain populations.

In median and wet years more water will be available and can be used to increase the extent of inundation in forest wetlands and to increase the duration of flooding. Greater flows from Gunbower Creek to the forest increase the extent of aquatic habitat and connectivity between aquatic habitats within the forest and connectivity between Gunbower Creek, the forest and the Murray River.

Although ecological objectives are generally specified in terms of the vegetation communities to be inundated, a range of other flora and fauna outcomes are targeted. The key outcomes are presented for each vegetation community in Table 3.

Table 3: Ecological objectives for targeted water use

Scenario	**Extreme dry**	**Dry**	**Median**	**Wet**
Ecological Watering Objectives/WMA	Avoid damage to key environmental assets	Ensure ecological capacity for recovery	Maintain ecological health and resilience	Improve and extend healthy and resilient aquatic ecosystems
Gunbower Creek objectives	Provide sustained flow in winter and spring to: • maintain aquatic habitat to support local fish populations • maintain passage at fishways in winter and spring • maintain aquatic habitat below Koondrook Weir.	Provide sustained flow in winter and spring with one or more freshes to: • maintain aquatic habitat to support local fish populations • maintain passage at fishways in winter–spring • maintain aquatic habitat below Koondrook Weir • support fish breeding. Provide connecting flows to allow movement of fish between the creek and the forest.	Provide sustained flow in winter and spring with two or more freshes to: • maintain aquatic habitat to support local fish populations • maintain passage at fishways in winter and spring • maintain aquatic habitat below Koondrook Weir • support fish breeding. Provide sustained connecting flows to allow movement of fish between the creek and the forest.	Provide sustained flow in winter and spring with two or more freshes to: • maintain aquatic habitat to support local fish populations • maintain passage at fishways in winter and spring • maintain aquatic habitat below Koondrook Weir • support fish breeding Provide sustained connecting flows to allow movement of fish between the creek and the forest.
Forest watercourse objectives	Provide baseflow in forest watercourses in winter and spring to: • maintain riparian vegetation health • maintain semi-permanent wetlands • maintain deep-pool habitat in forest watercourses for fish, turtles and invertebrates.	Provide baseflow in forest watercourses in winter and spring with one or more freshes to: • maintain riparian vegetation health • provide dispersal opportunities for fish between the river, forest and Gunbower Creek • support breeding by some waterbirds along watercourses and temporary forest wetlands • process and export organic matter and reduce blackwater risks.	Provide baseflow in forest watercourses in winter and spring to: • maintain riparian vegetation health • provide dispersal opportunities for fish between the river, forest and Gunbower Creek • support breeding by some waterbirds along watercourses and temporary wetlands • process and export organic matter and reduce blackwater risks.	Provide baseflow in forest watercourses in winter and spring to: • maintain riparian vegetation health • provide dispersal opportunities for fish between the river, forest and Gunbower Creek • support breeding by some waterbirds along watercourses and minor wetlands • process and export organic matter and reduce blackwater risks.

Scenario	Extreme dry	Dry	Median	Wet
Ecological Watering Objectives/WMA	Avoid damage to key environmental assets	Ensure ecological capacity for recovery	Maintain ecological health and resilience	Improve and extend healthy and resilient aquatic ecosystems
Permanent and semi-permanent wetland objectives	Maintain refuge pools in permanent wetlands with seasonal water level variation to: • provide aquatic refuge for fish, invertebrates, turtles and birds • maintain fringing aquatic plant communities • connect wetlands via watercourses and provide recolonisation/dispersal opportunities within the forest for aquatic fauna • maintain vegetation structure and prevent river red gum encroachment.	Fill permanent and semi-permanent wetlands in winter and spring, and provide a fresh to inundate wetland fringes to: • maintain aquatic habitat for fish, invertebrates, turtles and birds throughout the year • inundate fringing reedy vegetation in early spring to promote breeding by fish, frogs, turtles and waterbirds • support breeding by waterbirds which have a requirement for inundation, including waterfowl and ibis • connect wetlands via watercourses and provide recolonisation/dispersal opportunities within the forest for aquatic fauna • maintain vegetation structure and prevent river red gum encroachment.	Provide deep wetland inundation and sustained connecting flows to surrounding forest to: • maintain aquatic habitat for fish, invertebrates, turtles and birds throughout the year • inundate fringing reedy vegetation to promote breeding by fish, frogs, turtles and waterbirds • provide open water habitat for breeding waterfowl • support breeding by colonial nesting waterbirds with a requirement for a short period of inundation in fringing river red gum including ibis, darter and spoonbill • connect wetlands via watercourses and provide recolonisation/dispersal opportunities within the forest for aquatic fauna • maintain vegetation structure and prevent river red gum encroachment.	Provide deep inundation and sustained connecting flows to surrounding forest to: • maintain aquatic habitat for fish, invertebrates, turtles and birds throughout the year • inundate fringing reedy vegetation to promote breeding by fish, frogs, turtles and waterbirds • provide open water habitat for breeding waterfowl • support breeding by colonial nesting waterbirds with a requirement for a long period of inundation in fringing river red gum including egret and heron • connect wetlands via watercourses and provide recolonisation/dispersal opportunities within the forest for aquatic fauna • maintain vegetation structure and prevent river red gum encroachment.

Scenario	Extreme dry	Dry	Median	Wet
Ecological Watering Objectives/WMA	Avoid damage to key environmental assets	Ensure ecological capacity for recovery	Maintain ecological health and resilience	Improve and extend healthy and resilient aquatic ecosystems
River red gum with flood-dependent and flood-tolerant understorey objectives	Inundate low lying river red gum to maintain health of trees.	Inundate river red gum to: • maintain health of river red gum trees • maintain productivity of river red gum understorey including terete culm sedge and Warrego summer grass • inundate organic debris, reduce summer blackwater risks and export organic matter to Murray River • allow fish to return to permanent habitat during the flood recession.	Inundate river red gum to: • maintain growth of river red gum trees • promote aquatic plant growth in understorey including Moira grass, milfoil and spike sedge • support post-flooding productivity of river red gum understorey including terete culm sedge and Warrego summer grass • provide waterbird feeding habitat • inundate organic debris, reduce summer blackwater risks and export organic matter to Murray River • allow fish to return to permanent habitat on the flood recession.	Inundate river red gum to: • maintain growth of river red gum trees • promote aquatic plant growth in understorey including Moira Grass, milfoil and spike sedge • support post-inundation productivity of river red gum understorey including terete culm sedge and Warrego summer grass • provide waterbird feeding habitat • inundate organic debris, reduce summer blackwater risks and export organic matter to Murray River • allow fish to return to permanent habitat on the high flow recession.
Black box woodland objectives	None.	None.	Inundate black box to maintain tree health and understorey productivity and composition.	

3. Watering objectives

The water regimes required to achieve the ecological objectives described in section 2.3 may be determined from information on the ecology of key species, forest hydrology and observed responses to managed floods.

Table 4: Inundation requirements of water management areas in Gunbower Forest

Water management area	Total area in forest (ha)[1]	Per cent of forest area	Flood frequency (no. of years in 10)	Maximum interval between events[2]	Inundation duration	Season
Permanent wetlands	382	2	10	2	7-12 months (persisting for 12 months in nearly all years)	Winter/spring
Semi-permanent wetlands	992	5	6-9	2	5-8 months	Winter/spring to mid summer
River red gum with flood-dependent understorey	8,423	45	7-9	3	4 months (range of 1-8 months)	Winter/spring
River red gum with flood-tolerant understorey	4,309	25	3 (range of 1-4 months)	Not specified	2.5 months (range of 1-4 months)	Spring
Black box woodland	3,126	14	1	3-7	1 month (range of 1-4 months)	Spring
Grey box woodland	1,768	9	Grey box is located at higher elevations on the floodplain and is rarely inundated. Frequent or prolonged inundation may adversely impact the health of these communities.			

Notes:

1 Water management area is taken from (MDBA 2011b).
2 Inundation interval recommendation is taken from MDBA (2011a) and Roberts and Marston (2011).

Source: Ecological Associates 2006

Options (Table 5) have been developed for the use of environmental water to re-establish the water regime of Gunbower Forest closer to the water requirements set out in Table 3. Principally, these water-use options involve:

- releasing water from Gunbower Creek to Gunbower wetland and forest areas
- using water to maintain through-flow in Gunbower Creek.

Environmental water delivery is limited to the capacity of Gunbower Creek. The channel capacity is limited to 1,650 ML/d as far as the Hipwell Road regulator but there is the potential to introduce up to 250 ML/d via the 6/1 Channel below the regulator when water is being diverted to the forest. Together these flows allow a maximum environmental water delivery of 1,900 ML/d. The available inflows must be shared between the two principle delivery points: Hipwell Road regulator and Koondrook Weir. Thus, when Hipwell Road regulator is operating at its full capacity of 1,650 ML/d the maximum passing flow at Koondrook Weir is limited to 250 ML/d.

The water use options presented below describe the maximum environmental water release that would be possible if there were no constraints and without regard for recent watering history at the site. In reality, delivery of environmental water will be influenced by a number of factors, including delivery constraints, antecedent conditions and risks, all of which will require assessment prior to the commencement of a watering action.

The water delivery options presented in this document are likely to be impacted by the need to supply irrigation water from Gunbower Creek and the National Channel during filling at Kow Swamp, which reduces delivery capacity. When the capacity of Gunbower Creek is constrained by irrigation demand, the delivery of environmental flow in Gunbower Creek would be reduced as a first option and flows to the forest as a second option. Access to channel capacity during the winter shut down period (15 May to 15 August) may be constrained by system maintenance requirements.

Similarly, delivery will also be influenced by antecedent conditions, as well as any risks that may be present at the site – for example, environmental demand is likely to be reduced if the required wetland and forest inundation were supplied by overbank flows from the Murray River. As a result, further assessment of the site conditions and constraints will be required before delivery options are implemented.

These issues are discussed further in section 5 of this document.

Table 5: Potential water-use management options under different water availability scenarios

Ecological watering objectives	Extreme dry Avoid damage to key environmental assets	Dry Ensure ecological capacity for recovery	Median Maintain ecological health and resilience	Wet Improve and extend healthy and resilient aquatic ecosystems
Watering targets	Provide winter/spring flow to Little Reedy Lagoon Complex and Little Gunbower complex semi-permanent wetlands to maintain open water habitat and temporarily inundate fringing vegetation, or Provide water in winter and spring to maintain Black Swamp and Little Reedy Lagoon permanent wetlands.	Provide winter/spring/summer inflows to the forest to: • fill permanent and semi-permanent wetlands • fill forest watercourses and provide connected aquatic habitat between Gunbower Creek, the forest and the Murray River • inundate the fringes of semi-permanent wetlands between June and November (inflow of 920 ML/d) • inundate river red gum with flood-dependent understorey for six weeks in July/August (inflow of up to 1,650 ML/d).	Provide winter/spring/summer inflows to the forest to: • fill permanent and semi-permanent wetlands • fill forest watercourses and provide connected aquatic habitat between Gunbower Creek, the forest and the Murray River • inundate the fringes of semi-permanent wetlands between June and November (inflow of 920 ML/d) • inundate river red gum with flood-dependent understorey for eight weeks in June/July/August (inflow of up to 1,650 ML/d).	Provide winter/spring/summer inflows to the forest to: • fill permanent and semi-permanent wetlands • fill forest watercourses and provide connected aquatic habitat between Gunbower Creek, the forest and the Murray River • inundate the fringes of semi-permanent wetlands between June and November (inflow of 920 ML/d) • inundate river red gum with flood-dependent understorey for 14 weeks in June/July/August/September (inflow of up to 1,650 ML/d).
	Provide a passing flow at the Koondrook Weir throughout the year to maintain passage at Gunbower Creek weirs and to provide aquatic habitat in Lower Gunbower Creek.			
Management action (Also refer to schedule in Table 6.)	1. Release up to 1,500 ML at up to 50 ML/d at Black Swamp regulator in August and September. 2. Release up to 2,000 ML at up to 30 ML/d at Reedy Lagoon regulator in August and September. 3. Pass 500 to 700 ML/d at Koondrook Weir: 15 May to 30 November. 4. Release up to 300 ML/d from the Little Gunbower, Yarran and Hipwell Road regulators: 1 June to 31 December.	1. Release 300 to 1,650 ML/d from the Little Gunbower, Yarran and Hipwell Road regulators: May to January. 2. Pass 250 to 700 ML/d at Koondrook Weir throughout the year.	1. Release 300 to 1,650 ML/d from the Little Gunbower, Yarran and Hipwell Road regulators: May to February. 2. Pass 250 to 700 ML/d at Koondrook Weir throughout the year.	1. Release 300 to 1,650 ML/d f rom the Little Gunbower, Yarran and Hipwell Road regulators: May to February. 2. Pass 250 to 700 ML/d at Koondrook Weir throughout the year.

Based on the proposed water use management options (Table 5) under different water availability scenarios, seasonal flow regimes have been developed for this document and are provided in Table 6.

Extreme dry scenario

In the extreme dry scenario it may be possible to provide through-flow in Gunbower Creek between May and November. A seasonal flow regime profile (Table 6) proposes a peak of 700 ML/d in August, September and October which would maintain flowing reaches, inundate fringing habitat, maintain the function of fish passages and provide aquatic habitat in Gunbower Creek below Koondrook Weir.

A potential option for environmental water delivery under an extreme dry scenario is to release up to 300 ML/d to the forest, commencing in August, September, October and November (Table 6). Initially, the lower forest regulators would be operated to fill the permanent and semi-permanent wetlands, but as water backs up against the regulators, inflows would commence from Hipwell Road. Watering could:

- provide connectivity between the aquatic habitat of Gunbower Forest, Gunbower Creek and the Murray River
- maintain aquatic refuge habitat in wetlands
- maintain vegetation structure
- inundate low-lying river red gum near wetlands
- allow migration and dispersal of aquatic fauna.

Table 6: Flow regimes for Gunbower Creek and Gunbower Forest environmental water use

Month	Gunbower Creek flow at Koondrook Weir								Forest and wetlands							
	Extreme dry		Dry		Median		Wet		Extreme dry		Dry		Median		Wet	
	ML/d	Days	ML/d	Days	ML/d	Days	ML/d	Days	ML/d	Days	ML/d	Days	ML/d	Days	ML/d	Days
May	500	31	500	31	500	31	500	31	0	0	0	0	0	0	300	31
June	500	30	500	30	500	30	500	15	0	0	600	30	920	15	920	15
							250	15					1,650	15	1,650	15
July	600	31	250	31	250	31	250	31	0	0	1,650	31	1,650	31	1,650	31
August	700	31	250	16	250	15	250	31	300	31	1,650	15	1,650	15	1,650	31
			700	15	700	16					920	16	920	16		
September	700	30	700	30	700	30	250	30	300	30	920	30	920	30	1,650	30
October	700	31	700	31	700	31	700	31	300	31	920	31	920	31	920	31
November	500	30	500	30	500	30	500	30	300	30	920	30	920	30	600	30
December	0	0	300	31	300	31	300	31	0	0	600	31	600	31	600	31
January	0	0	200	31	300	31	300	31	0	0	300	31	600	31	600	31
February	0	0	200	28	300	28	300	28	0	0	0	0	300	31	300	28
March	0	0	200	31	300	31	300	31	0	0	0	0	0	0	0	0
April	0	0	300	30	500	30	500	30	0	0	0	0	0	0	0	0

Dry scenario

In a dry year additional environmental water reserves may allow for delivery over a longer period and at higher peak flows (Table 6) to match native fish breeding and migration cues. An option in a dry scenario is to provide a passing flow in Gunbower Creek throughout the year.

It is likely that this profile will be interrupted to some extent by irrigation demand. This may represent a risk to fish by providing rising flows that initiate breeding behaviours but then failing to provide the sustained high flows required to complete breeding successfully.

An additional option in a dry scenario is to deliver water to forest wetlands, commencing in May using the lower forest regulators. In July and August releases could be increased to 1,650 ML/d for six weeks from the start of July until the irrigation season commences on 15 August. This flow would replicate a Murray River inflow of 38,000 ML/d and inundate 4,710 hectares of the forest. The wetlands would provide deep aquatic habitat with flooded fringes of emergent vegetation. Inundation of the forest understorey would provide extensive, connected, temporary aquatic habitat for fish, invertebrates, frogs and waterbirds and maintain the health of river red gum trees and the productivity of understorey vegetation. Importantly, understorey vegetation would remain productive into summer after flood water recedes and sustain terrestrial fauna including swamp wallabies and birds.

Releases from Hipwell Road regulator would be decreased to 920 ML/d in late August, September, October and November and then to 600 ML/d in December and 300 ML/d in January. Watering events of this duration and magnitude should maintain water under trees and in wetlands and provide breeding opportunities for waterfowl and some colonial nesting waterbirds, particularly ibis.

It is necessary for the passing flow at Koondrook Weir to fall to 250 ML/d when the Hipwell Road regulator is releasing 1,650 ML/d, as this represents the available remaining capacity of the system.

Irrigation demand in dry years is likely to reduce the capacity to make environmental water releases. The high passing flow in Gunbower Creek in spring and summer would be reduced as the first option. The peak flow of 1,650 ML/d at Hipwell Road occurs before the irrigation season and would be unlikely to be disrupted by the need to supply water for irrigation demands, but may be disrupted by diversions to mid-Murray storages. The release rates of 920 ML/d may not be achievable as far into spring and summer as has been proposed as summer irrigation demand increases. Access to channel capacity during the winter shutdown period (15 May to 15 August) may be constrained by system maintenance requirements.

Median scenario

Under median conditions it may be possible to increase the duration of inundation in the river red gum forest areas by initiating the release of 1,650 ML/d 15 days earlier than the dry year (Table 6). There is a risk that earlier releases will have reduced additional benefit to the ecosystem as plant growth and animal breeding may not respond to the same extent to inundation in winter.

The release of water at rates of at least 600 ML/d would extend into summer, if an ecological need was identified. For example, flows until the end of January would prolong inundation and could support breeding by a wider range of colonial nesting waterbirds including darter and spoonbill. A release of this magnitude would ensure that water levels remain high below nesting areas in wetlands and surrounding red gum and minimise the likelihood of the failure of birds to complete breeding. Extending releases into summer would require careful monitoring to ensure that blackwater conditions did not develop.

In a median scenario some Murray River inflows to the forest would be expected. This is likely to improve ecological outcomes by providing additional inundation and supplying chemical cues in high flows for breeding by aquatic fauna. The release of water from Gunbower Creek to the forest would be interrupted by Murray River inflows which reduce the requirement to operate the forest regulators. The releases from Gunbower Creek could resume when forest water levels fall, to prolong inundation and sustain breeding and other outcomes.

Irrigation demand will also reduce the potential environmental water delivery. Gunbower Creek passing flows should be reduced before environmental releases to the forest are reduced. Access to channel capacity during the winter shutdown period (15 May to 15 August) may be constrained by system maintenance requirements.

Wet scenario

In a wet year, irrigation demand is likely to be low in spring as rainfall meets most irrigator water requirements. There may be an opportunity to utilise all the capacity of Gunbower Creek for environmental needs until the end of September by releasing up to 1,650 ML/d from Hipwell Road regulator and using all remaining capacity to provide a passing flow in Gunbower Creek (Table 6). The release of up to 1,650 ML/d would ideally last for 14 weeks, commencing on 15 June and extending to the end of September. The extensive and sustained inundation is expected to support waterbird breeding by all colonial nesting waterbirds including intermediate and great egret as well as supporting major breeding events by fish, invertebrates, frogs and turtles.

Access to channel capacity during the winter shutdown period (15 May to 15 August) may be constrained by system maintenance requirements.

PART 2:

Water use strategy

4. Environmental water requirements

4.1 Baseline flow characteristics

Average daily flows anticipated in each month under various climate conditions are presented for the Murray River downstream of Torrumbarry Weir in Table 7. Note that the values in Table 7 are derived independently for each month. Other sites of interest are presented in Appendix 2.

This information is sourced from the MSM-Bigmod model of the Murray River system with TLM deliveries in place (run #22061). This establishes the baseline conditions after the delivery of environmental flows under TLM. Actual flows may be higher or lower than those presented below if the delivery of TLM water differs from that assumed in MSM-Bigmod. For example, if TLM water modelled as being delivered to ecological assets downstream of Torrumbarry Weir is diverted to sites upstream, then the baseline flows at downstream of Torrumbarry Weir would be lower than those shown in Table 7.

Table 7 shows that minimum flows downstream of Torrumbarry Weir are in the order of 1,500–2,500 ML/d (245 ML/d for August) in a dry year, while in a wet year, spring flows would be expected to exceed 25,000 ML/d (the flow threshold required for significant inundation is 25,000 ML/d). Average daily flow tables in Appendix 2 highlight that contributions from the mid-river tributaries (Broken Creek and Goulburn and Campaspe Rivers) are minimal in dry years.

Table 7: Average daily flows (ML/d) for the Murray River downstream of Torrumbarry Weir (1895–2009)

Month	Very dry year (minimum on record)	Dry year (30th percentile daily flow)	Median year (50th percentile daily flow)	Wet year (70th percentile daily flow)
Jul	1,752	6,073	9,271	18,278
Aug	245	6,924	13,124	24,475
Sep	2,118	7,938	15,286	26,881
Oct	2,113	6,375	10,322	19,228
Nov	1,659	6,601	8,873	12,869

Month	Very dry year (minimum on record)	Dry year (30th percentile daily flow)	Median year (50th percentile daily flow)	Wet year (70th percentile daily flow)
Dec	1,913	6,458	7,919	9,562
Jan	2,548	5,173	5,777	6,516
Feb	2,573	4,860	5,677	6,441
Mar	2,118	3,700	4,311	4,781
Apr	1,880	4,398	5,413	6,572
May	1,537	3,849	4,898	6,851
Jun	1,902	3,642	5,236	9,075

At Barmah, river flows in the Murray River are limited by geomorphologic factors. The channel capacity in the Murray River at the Barmah Choke is limited to 8,500 ML/d[1] (MDBA 2009) and at greater flows flooding of Barmah and Millewa Forests occurs. As river levels rise, the Edward River and Gulpa system carry a larger proportion of flows northwards through New South Wales, bypassing the Murray River downstream of Echuca and the Gunbower and Koondrook-Perricoota forests.

The maximum flows attained in the Murray River immediately downstream of Barmah are therefore approximately 30,000 ML/d, comprising 8,500 ML/d passing through the Choke and approximately 20,000 ML/d in floodwater from the Barmah floodplain. Larger flows at Torrumbarry involve the additional contributions of the Goulburn and Campaspe rivers (URS 2001).

Similarly, effluents to the Koondrook-Perricoota forest in New South Wales limit flow at Koondrook, just downstream of Gunbower Island, to approximately 32,000 ML/d (URS 2001).

4.2 Environmental water demands

In Section 3, flow targets are specified for each of the four climate scenarios. The volume required to deliver each event will depend on the ambient conditions in the river and the ability to enhance a natural flow event. The net water use from floodplain inundation will be dependent on the antecedent conditions.

For the purposes of estimating environmental water demand, the operational triggers in Section 5 of this document have been adopted.

The frequencies of the specified flows were estimated using data extracted from the MSM-Bigmod model with TLM water deliveries already in place. This includes assessing overbank flows from the Murray River, as well as deliveries via the Hipwell Road regulator under TLM (MSM-Bigmod run #22061). This establishes the baseline conditions after the delivery of environmental flows under TLM program.

Actual recurrence intervals may be higher or lower than those presented below if the delivery of TLM water differs from that assumed in MSM-Bigmod. For example, if TLM water modelled as being delivered to Gunbower Forest is instead diverted to other TLM sites, then the average recurrence interval of events would be lower than those shown below.

1 At the Choke, which equates to a flow of 10,600 ML/d at Yarrawonga Weir, assuming 2,100 ML/d is diverted through the Edward River and Gulpa Creek offtakes.

The results of this analysis are shown in Table 8. In this analysis the Murray River flow threshold equivalent to overtopping is assumed to be 16,000 ML/d for the lower landscape regulators and 30,000 ML/d for the mid-forest regulator.

These results show that, even with TLM deliveries via the Hipwell Road regulator, the events do not occur at the required frequency. Additionally, the results indicate that with the exception of some of the short-duration permanent wetland water events in very dry years, none of the events which occur meet the required duration. Therefore, additional water will be required to meet the flow targets. Where the environmental flow recommendations were specified as a range of possible durations, a fixed duration of events has been assumed in this analysis.

Table 8: Average recurrence interval for the target flow events for Gunbower Forest (1895–2009)

Water scenario	Event	No. of years in 10 with event of any duration (all years)	No. of years in 10 with event of specified duration (all years)	No. of years in 10 with event of any duration (water scenarios only)	No. of years in 10 with event of specified duration (water scenarios only)
Very dry	93 ML/d for 16 days at Black Swamp regulator, August–September*.	8	6.6	7.4	5.9
	330 ML/d for 16 days at Reedy Lagoon regulator, August–September*.	8	6.6	7.4	5.9
	Passing flow of between 500 and 700 ML/d at Koondrook Weir, May–November.	9.7	0	9.7	0
	Flow into Gunbower Forest of between 300 and 920 ML/d, August–November*.	7.9	1.1	7.4	0.6
Dry	Flow into Gunbower Forest of between 300 and 1,650 ML/d, May–January*.	8.7	0	9.1	0
	Passing flow of between 200 and 700 ML/d at Koondrook Weir, year round.	9.9	0	10	0
Medium	Flow into Gunbower Forest of between 200 and 1,650 ML/d, May–March*.	8.4	0	8.6	0
	Passing flow of between 250 and 700 ML/d at Koondrook Weir, year round.	9.9	0	8.6	0
Wet	Flow into Gunbower Forest of between 200 and 1,650 ML/d, May–February*.	7.9	0	8.6	0
	Passing flow of between 250 and 700 ML/d at Koondrook Weir, year round.	9.9	0	10	0

* Forest regulators are not individually modelled in MSM-Bigmod, event occurrence was assessed based on modelled Murray River flow and modelled diversions through the upper forest channel (Hipwell Road) and to Koondrook Weir.

Note: See Table 5 for more detail on the specified events.

The volume of additional water that would be required to meet the flow targets was calculated. For the flows through the regulators and into the forest, this calculation supplemented existing flows through the use of the Hipwell Road scheme (up to the required flow rate). For passing flows at Koondrook Weir, this calculation supplemented existing flow at Koondrook Weir. For the continual flow events, each day below the specified flow target was supplemented. A fixed duration of events has been assumed in this analysis.

The calculation of the additional water (Table 9) that would be required to meet the flow targets was not limited by likely available channel capacity. In other words, these are the volumes of water that would be required assuming no constraints on delivery. Also, the additional volumes do not take into account delivery losses or return flows which are significant (refer Table 15). Hence the additional volumes are a gross rather than net figure.

These calculations were based on supplementing the existing natural, consumptive and TLM flows. Supplementary volumes may be higher or lower than those presented in Table 9 if TLM volumes differ from that assumed in MSM-Bigmod. For example, if TLM water modelled as being delivered to Gunbower Forest is instead diverted to other TLM sites, then the additional volume required to achieve the target flows would be greater than that shown below. As a result, the figures in Table 9 should be interpreted as indicative only, and will be refined as operational experience increases.

Under the scenario modelled, an average of 192,000 ML each year of TLM water was delivered to Gunbower Forest. This volume varied with climate conditions. On average 109,000 ML/year was delivered in very dry years; 135,000 ML/year was delivered in dry years; 156,000 ML/year was delivered in median years; and 192,000 ML/year was delivered in wet years.

Table 9: Range of additional volumes required to achieve the target flows across all water scenarios

Climate scenario	Flow location	Maximum annual volume in given water scenario (ML/year)	Average annual volume in given water scenarios (ML/year)
Very dry	Flow into forest	36,600	22,300
	Koondrook Weir	128,500	72,100
Dry	Flow into forest	210,900	139,000
	Koondrook Weir	91,000	65,900
Medium	Flow into forest	258,700	179,000
	Koondrook Weir	97,600	78,800
Wet	Flow into forest	291,300	165,000
	Koondrook Weir	89,400	61,800

The frequencies of the specified flow targets in all years and the specific water scenarios are shown in Table 10.

Table 10: Average recurrence interval for the target flow events for Gunbower Forest (1895–2009)

Water scenario	Event	Time	No. of years in 10 with event of specified duration	
			Current	Proposed
Very Dry	93 ML/d for 16 days at Black Swamp regulator.	Aug–Sep	6.6	9.8
	330 ML/d for 16 days at Reedy Lagoon regulator.	Aug–Sep	6.6	9.2
	Passing flow of between 500 and 700 ML/d at Koondrook Weir.	May–Nov	0	3
	Flow into Gunbower Forest of 300 ML/d.	Jun–Dec	1.1	10
Dry	Flow into Gunbower Forest of between 600 and 1,650 ML/d.	May–Jan	0	4.2
	Passing flow of between 200 and 700 ML/d at Koondrook Weir.	All year	0	3.9
Medium	Flow into Gunbower Forest of between 300 and 1,650 ML/d.	May–Mar	0	2.2
	Passing flow of between 250 and 700 ML/d at Koondrook Weir.	All year	0	1.8
Wet	Flow into Gunbower Forest of between 300 and 1,650 ML/d*.	May–Feb	0	3.2
	Passing flow of between 250 and 700 ML/d at Koondrook Weir.	All year	0	5

* Forest regulators are not individually modelled in MSM-Bigmod, event occurrence was assessed based on modelled Murray River flow and modelled diversions through the upper forest channel (Hipwell Road) and the Koondrook Weir.

5. Operating regimes

5.1 Introduction

This section of the delivery document presents possible operational triggers for implementation of the environmental watering options outlined in this document. These triggers should be used as a guide and refined based on operational experience after watering events. Operational water delivery includes several steps including:

- identifying target environmental flows for the coming season, based on water availability and recent watering history
- defining triggers to commence and cease delivery of the recommended flows
- defining triggers for opening or closing environmental flow regulators
- identifying any constraints and/or risks associated with water delivery, such as the potential for flooding of private land, delivery costs, limits on releases from flow-regulating structures and interactions with other environmental assets.

5.2 Identifying water scenarios

The water scenarios are determined in this document using the combined Victorian and NSW Murray allocations announced at the start of July, as shown in Table 11. This is the sum of announced allocation (as a percentage of entitlement) to Victorian high-reliability water shares, Victorian low-reliability water shares, NSW high-security water shares and NSW general-security water shares. Allocations, rather than flow in the river, have been used to determine triggers for water deliveries because water can be delivered through the forest regulators without necessarily requiring flow cues in the Murray River.

Table 11: Identifying water scenarios

Water scenario	Combined NSW/Vic Murray system allocations at the start of July	Frequency
Very dry	Less than 223%	30%
Dry	223% to 279%	20%
Median	280% to 330%	18%
Wet	331% or more	32%

If flow or resource availability conditions change significantly, such as in a major spring run-off event, consideration should be given to aiming for higher volume events associated with a wetter climate year. The selection of the suite of flow targets should be flexible and in response to conditions in the Murray River. Reference should also be made to the seasonal forecasts from the Bureau of Meteorology to assess the likely future conditions. Seasonal climate forecasts from the Bureau are available <http://www.bom.gov.au/climate/ahead/rain_ahead.html> as are seasonal streamflow forecasts <http://www.bom.gov.au/water/ssf/>.

5.3 Delivery triggers and environmental watering options

Proposed operational triggers for delivering the environmental watering options are presented in Table 12 including triggers for commencing delivery of each event. All deliveries to extend or initiate events are assumed to occur through Gunbower Creek and the Hipwell Road channel system.

Triggers for ceasing delivery have not been specified because the annual environmental water demand is similar across all water scenarios. The only exception to this is the very dry climate year, which has a considerably lower flow into the forest than a dry, medium or wet year.

It is important to note that environmental water delivery will be adaptively managed to reflect local site conditions, risks and delivery constraints. As a result, watering events may vary from those presented in this document.

Table 12: Summary of operational regime for achievement of environmental objectives

Water scenario	Flow objective	Season/ timing	Average return period	Trigger for delivery	Trigger for ceasing delivery (if applicable)
Very Dry	93 ML/d for 16 days at Black Swamp regulator.	Aug–Sep	Every very dry year.	Would be delivered as part of flows into Gunbower Forest and to Koondrook Weir.	Switch to dry-year recommendations if allocation increases significantly by end of November to extend deliveries into summer/autumn.
	330 ML/d for 16 days at Reedy Lagoon regulator.	Aug–Sep			
	Passing flow of between 500 and 700 ML/d at Koondrook Weir.	May–Nov		Maintain through the specified period.	
	Flow into Gunbower Forest of 300 ML/d.	Aug–Dec		Maintain through the specified period.	
Dry	Flow into Gunbower Forest of between 600 and 1,650 ML/d.	Jun–Dec	Every dry year.	Maintain through the specified period.	N/A
	Passing flow of between 200 and 700 ML/d at Koondrook Weir.	Year round		Maintain through the specified period.	
Medium	Flow into Gunbower Forest of between 300 and 1,650 ML/d.	May–Mar	Every medium year	Maintain through the specified period.	N/A
	Passing flow of between 250 and 700 ML/d at Koondrook Weir.	Year round		Maintain through the specified period.	
Wet	Flow into Gunbower Forest of between 300 and 1,650 ML/d.	May–Feb	Every wet year	Maintain through the specified period.	N/A
	Passing flow of between 250 and 700 ML/d at Koondrook Weir.	Year round		Maintain through the specified period.	

5.4 Wetland regulators

There are various regulators and effluent creeks which allow water to enter Gunbower Forest from the Murray River. The capacities of the regulators and creeks are shown in Table 13 (MDBA 2010c). This table shows that the regulators and effluent creeks commence to flow at the Murray River (downstream of Torrumbarry Weir) at flows of 15,200 ML/d. This flow is greater than the 50th percentile daily flow at this site in all months except August (the 50th percentile daily flow for August is 15,286 ML/d).

Environmental water delivery to the forest and wetlands of Gunbower Forest relies on the head difference provided by the weirs on Gunbower Creek and the receiving channels in the forest. The head difference decreases as these receiving channels fill, which occurs when high river levels introduce water to the forest. The head difference is gradually lost as river flows approach 30,000 ML/d and no environmental water releases can be made to the forest to increase the flow peak at flows above this level.

Table 13: Wetland regulator and effluent creek commence-to-flow and capacities

Regulator/effluent creek	Murray River (d/s Torrumbarry) commence-to-flow (ML/d)	Capacity at Murray River (d/s Torrumbarry) flows of 30,000 ML/d (ML/d)
Spur Creek	~16,000	~700
Yarran Creek (via Shillinglaws regulator)	~16,000	~2,500
Barham Cut (via Barham Cut regulator)	15,200	~100
Broken Axle Creek	18,300	Not specified
Wattles regulator	18,300	Not specified
Deep Creek	Not specified	100

Source: (MDBA, 2010b)

5.5 Channel capacity constraints

The ability to deliver water to Gunbower Forest via the Hipwell Road scheme and other regulators of Gunbower Creek is constrained by the limited capacity of Gunbower Creek and National Channel. Figure 6 shows likely spare channel capacity in Gunbower Creek in each different climate year (very dry, dry, median and wet). Spare capacity for environmental water delivery is reduced when Gunbower Creek is used to supply irrigation water between 15 August and 15 May. For example, around 1,000 ML/d of spare channel capacity is available in September in 50 per cent of years. This reduces to around 200 ML/d in March when the channel is being used for irrigation deliveries. This data was derived from analysis of the MSM Bigmod outputs under historic climate conditions with TLM deliveries in place (run #22061).

There is currently no delivery share in Gunbower Creek and thus there is no guarantee of access to channel capacity throughout the irrigation season. Instead, environmental water delivery relies on using spare capacity in the channel at times of low irrigation demand. This demand is typically low in spring when environmental demand may be highest.

There is a risk that the seasonal demand for irrigation water will change into the future. In recent drought years irrigation patterns have changed with a shift towards annual pasture (with spring and autumn watering) from perennial pasture (with peak summer watering). This change increases demand on channel capacity to supply water for irrigation in spring, reducing the channel capacity available to deliver environmental water.

The availability of spare capacity in the 6/1 channel outfall to Gunbower Creek has not currently been assessed. The outfall could be used to deliver greater flows of up to 250 ML/d through Gunbower Creek when the Hipwell Road regulator is diverting flows at or near capacity (see Section 10). This issue requires further investigation.

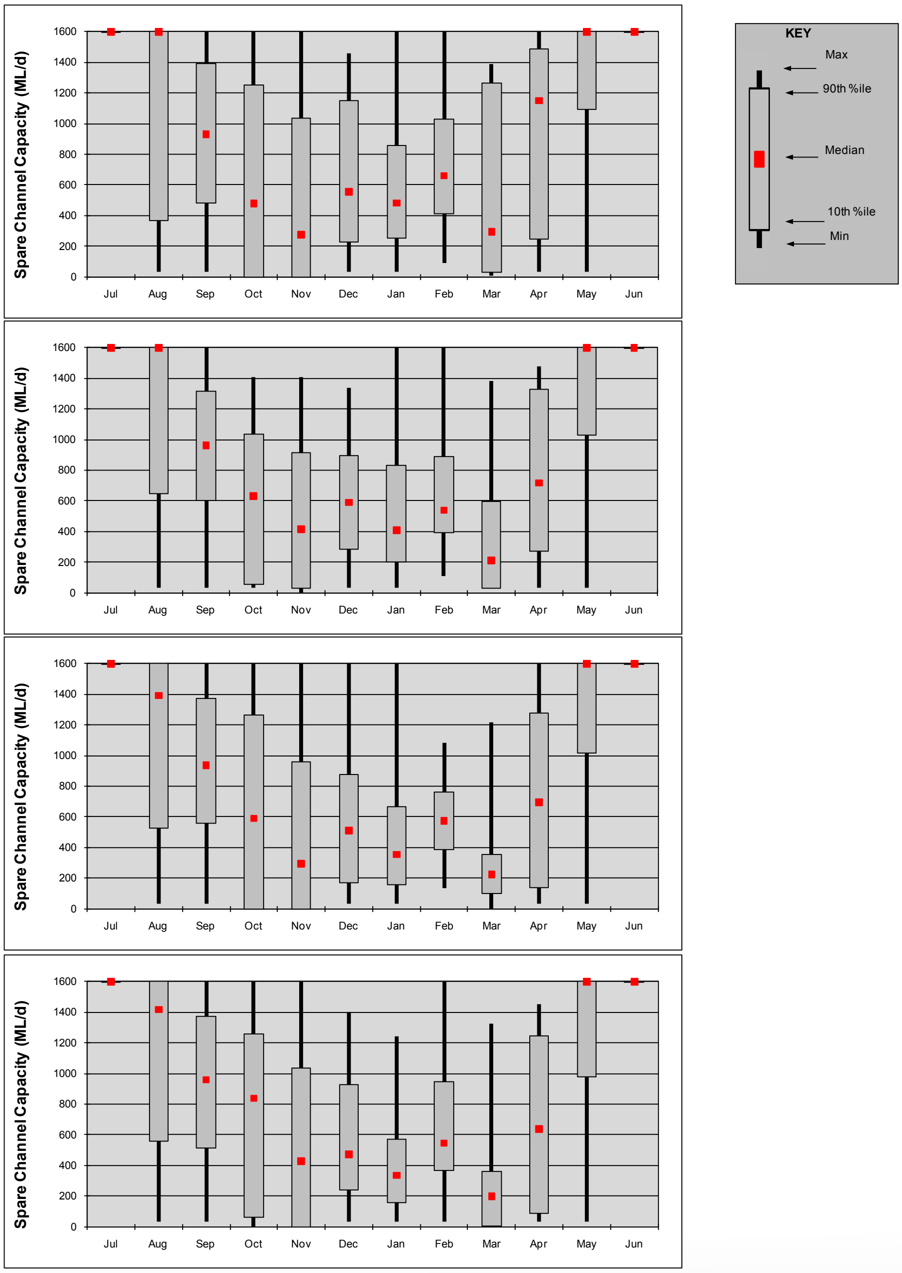


Figure 6: Spare channel capacity in Gunbower Creek upstream of the Hipwell Road Channel in (from top to bottom): very dry, dry, median and wet water scenarios.

Source: MSM Bigmod run # 22061 (post TLM; historical climate)

5.6 Storage releases

The release capacities of upstream Murray River and Goulburn system storages (Lake Hume, Yarrawonga Weir, Lake Eildon and Torrumbarry Weir) are not a constraint to delivering environmental flows to Gunbower Forest. However, flooding and flow peak attenuation between the storage release points and Gunbower Forest may constrain the ability to deliver large releases such as would be required for overbank flows.

5.7 Travel time

The travel time along the Murray River under regulated flow conditions is approximately four days from Hume Dam to Yarrawonga Weir and a further seven days from Yarrawonga Weir to Torrumbarry Weir. The travel time from Lake Eildon via the Goulburn River to the Murray River under regulated flow conditions is approximately seven days.

An example of a high flow event for the Murray River downstream of Torrumbarry Weir is shown in Figure 7. This example shows that high flows recorded downstream of Yarrawonga are significantly attenuated by the Barmah-Millewa Forest and contribute to long periods of sustained high flows at Torrumbarry Weir with low rates of rise and fall. Peak flow events recorded on the Goulburn River at Trawool then contribute to peak events at Torrumbarry on top of the more constant high flows from the Murray River.

Based on the hydrographs at these sites it is difficult to discern the travel time between Yarrawonga and Torrumbarry weirs, however, the travel time from Trawool to Torrumbarry appears to be in the order of six or seven days (travel time from Trawool to McCoys Bridge near the end of the Goulburn Valley is in the order of four days).

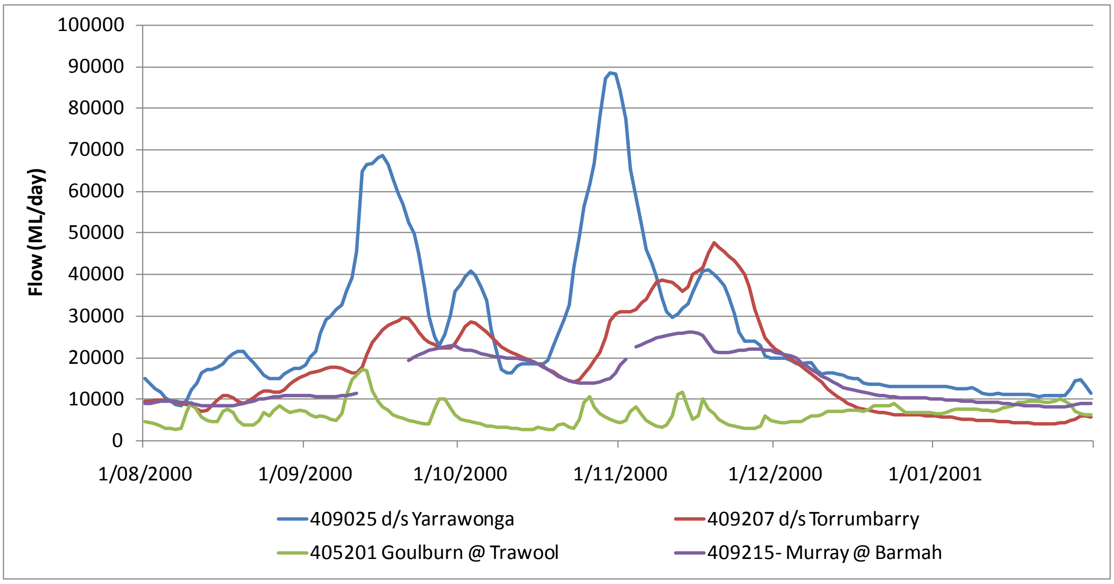


Figure 7: Murray River example event, spring 2000

5.8 Interactions with other assets

Gunbower Forest is ecologically continuous with Koondrook-Perricoota Forest and shares the Torrumbarry Weir pool as a common water source for environmental watering. Gunbower Forest is also downstream of the Barmah-Millewa Forest, Lower Goulburn floodplain and Campaspe River. Deliveries of water to these upstream and adjacent assets have the potential to interact with flow behaviour in the Gunbower Forest through the ability to re-divert return flows credited to environmental water managers from upstream. Water from the Gunbower Forest can also interact with downstream ecological assets on the Murray River, such as the Lindsay, Mulcra and Wallpolla islands.

5.9 Recreational users

There are no known adverse impacts on recreational users associated with water delivery through the forest. Water deliveries are likely to enhance recreational activities such as fishing.

5.10 Water delivery costs

5.10.1 Delivery costs

There are no delivery costs to environmental water holders if Victorian water shares are delivered via the river or natural carrier system (including Gunbower Creek) however, such access to these systems is based on 'interruptible supply'. If water is delivered via the National Channel during times of channel capacity constraint, then Goulburn-Murray Water's Torrumbarry System delivery charges would apply. These are $7.11/ML plus a $200 fee per service point. The Australian Government or its delivery partners would also require a delivery share if water is delivered during times of channel capacity constraint. Note that delivery and storage charges are subject to review on an annual basis, and additional fees and charges may apply. More information is available from Goulburn-Murray Water <http://g-mwater.com.au/customer-services/feesandcharges>.

State Water's delivery costs of NSW water shares in the Murray system for 2011-12 include a usage charge of $4.89/ML, plus an annual fee for high security of $2.85/ML and for general security, $2.32/ML. See the following reference for details: <http://www.statewater.com.au/Customer+Service/Water+Pricing>.

5.10.2 Victorian carryover costs

Goulburn-Murray Water charges per megalitre for water shares transferred from the spillable water account to an allocation bank account. The 2011-12 fees for transferring water from the spillable water account to an allocation bank account is $4.52/ML for the Murray system, $17.03/ML for the Campaspe system and $3.52/ML for the Goulburn system. More information is available from Goulburn-Murray Water <http://www.g-mwater.com.au/customer-services/carryover#1>.

6. Governance

6.1 Delivery partners, roles and responsibilities

Major strategic partners in delivering water to Gunbower Forest are presented in Table 14.

Table 14: Key stakeholders involved in environmental water management at Gunbower Forest

Agency	Description
MDBA	The Murray-Darling Basin Authority is responsible for the implementation of the TLM program and the operation of the Murray River.
North Central Catchment Management Authority	The North Central CMA is the Victorian Icon Site manager responsible for project management of flooding enhancement projects and ecosystem monitoring.
Department of Sustainability and Environment (DSE) Victoria	The DSE is responsible for implementing TLM in Victoria and is project owner and site owner for public land and manager of approvals/referrals for the state.
Victorian Environmental Water Holder (VEWH)	The VEWH is responsible for holding and managing Victorian environmental water entitlements and allocations throughout the state.
Parks Victoria	Parks Victoria is the land manager for the Murray River Reserve and Gunbower National Park.
Goulburn-Murray Water	Goulburn-Murray Water (G-MW) is the operator of the Torrumbarry Irrigation Area, as part of its role as resource manager for northern Victorian water systems.

Governance and planning arrangements for Gunbower Forest have been developed around its role as a Living Murray Icon Site. Regionally, icon site management is overseen by the Gunbower Forest Icon Site Management Committee chaired by the North Central CMA. It includes representatives from G-MW, MDBA, DSE, Parks Victoria, the Northern Victoria Irrigation Renewal Project, Gannawarra Shire Council and traditional owner groups.

DSE's primary interests in Gunbower Forest relate to the implementation of TLM. DSE is also the land manager responsible for Gunbower State Forest. Environmental water management is the responsibility of the Victorian Environmental Water Holder (since June 2011).

The chief executive officer of the North Central CMA acts as the Regional Icon Site Coordinator for Gunbower Forest and is responsible for delivery of the program. Accordingly, DSE has entered into a memorandum of understanding with the North Central CMA to establish a collaborative working relationship between the organisations, set out a common understanding of intent, and commit to sub-jurisdictional arrangements for delivery of TLM Business Plan.

Goulburn-Murray Water is the MDBA's delegated authority for construction at Gunbower Forest. As such, the state water authorities are responsible for detailed design and construction under the Environmental Water Management Plan, once an investment proposal has been approved by the MDBA.

Parks Victoria is the land manager for Gunbower National Park.

Koondrook-Perricoota management arrangements

Environmental watering of Gunbower Forest is coordinated with the Koondrook-Perricoota Forest in NSW through the Integrated Coordinating Committee (ICC). The committee includes representatives from the separate state steering committees including North Central CMA, Murray CMA, DSE, Forests NSW, G-MW, DSEWPaC and the MDBA.

The ICC identifies important areas where integration is required (such as water sharing, opening/shutting structures, implementation of monitoring) and will ensure that it occurs. The committee also identifies efficiencies, ensures cross-communication, consistency and information sharing, and determines priorities across the entire forest system.

6.2 Approvals, licenses, legal and administrative issues

6.2.1 Water shepherding and return flows

Table 15 below shows that large volumes are required to water river red gums and support colonial waterbird breeding events, however net consumption is significantly less. Around 25 per cent of total inflows for wetland watering,70 per cent for river red gum watering and 74 per cent for bird breeding, are returned to the Murray River during these events. The outflows are then available for reallocation downstream of Gunbower Forest. This volume and rate of return is not expected to vary significantly with different antecedent soil moisture conditions in the forest, because the rate of seepage from the heavy clay soils is fairly invariable (M Tranter (North Central CMA), pers. comm. 27 May 2011). The CMA's seepage rates are based on in-situ infiltration tests.

Table 15: Water use of different operational scenarios

Scenario	Inflow (ML)	Outflow (ML)	Evapo-transpiration (ML)	Soil seepage (ML)	Floodplain storage (ML)	Net water consumption per event (ML)
Wetland watering	29,400	7,200	9,400	12,500	500	22,300
River red gum watering (1,650 ML/d)	110,600	76,900	15,700	17,200	800	33,700
Bird breeding (1,650 ML/d)	209,900	154,200	28,700	21,700	5,300	55,700

Source: Water Technology, 2010

In Victoria, the policy position presented in the Northern Region Sustainable Water Strategy is to allow all entitlement holders to reuse or trade their return flows downstream (DSE, 2009), provided that:

- there is adequate rigour in the calculation and/or measurement of return flows
- the return flows meet relevant water-quality standards
- additional losses (if any) are taken into account
- the return flows can be delivered in line with the timing requirements of the downstream user, purchaser or environmental site
- the system operator can re-regulate the return flows downstream, with a known and immaterial spill risk, if the entitlement holder is requesting credits on a regulated system.

Commonwealth environmental water cannot currently be delivered from its licenses in Victoria, so allocations must be transferred to the VEWH for them to be used. If Commonwealth environmental water was transferred to the VEWH's flora and fauna entitlement, then return flows can be credited under clause 15 of the entitlement. Return flows can be re-credited to the flora and fauna entitlement at specified locations listed in the entitlement or in agreement with Goulburn Murray water and MDBA.

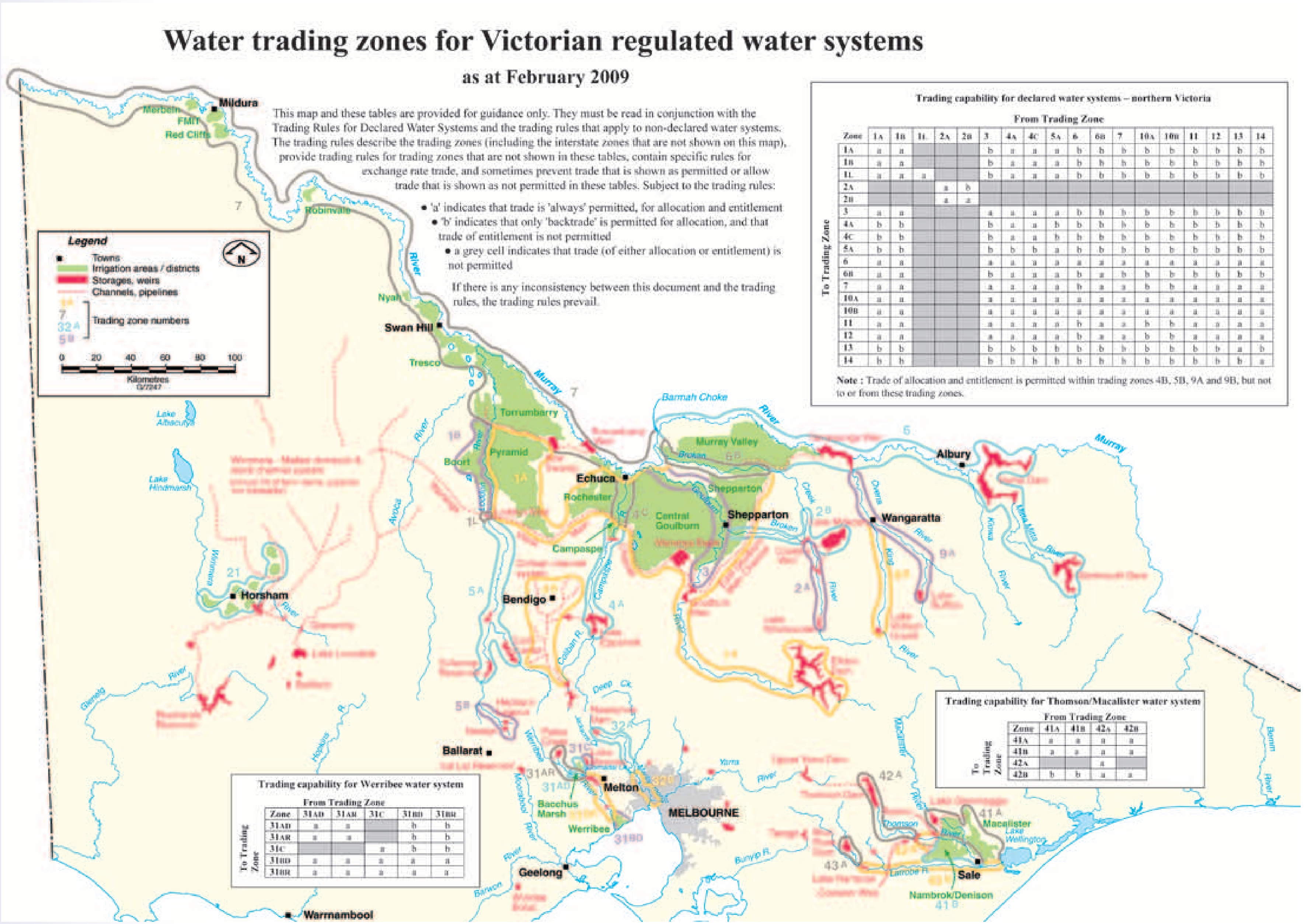
The assessment of the return flow calculations and crediting would be undertaken by Goulburn-Murray Water. Goulburn-Murray Water's assessment of credits would be subject to any rules set by the Victorian Minister for Water, as well as overall MDBA accounting arrangements and the availability of credits for Victoria. If these credits were granted, then the Commonwealth Environmental Water Office would need to discuss how the credits might subsequently be used with the VEWH, who would be granted the credits.

If environmental water holders have previously ordered water to be delivered to the Broken Creek, Goulburn or Campaspe Rivers and want to reuse the return flows in the Murray River, then credits for return flows to the Murray River can be granted under Goulburn-Murray Water's bulk entitlement for the Victorian Murray system or the entitlements held by the VEWH. This would be subject to agreement with Goulburn-Murray Water or the VEWH to have return flows credited to an allocation bank account.

6.3 Trading rules and system accounting

6.3.1 Water trading

Figure 8 shows a map of the Victorian and southern NSW water-trading zones. The trading rules for these zones are provided in Table 16. Gunbower Forest is located in trading zone 7 (Victorian Murray Barmah to South Australia).



Trading capability for declared water systems – northern Victoria

From Trading Zone (columns); To Trading Zone (rows)

Zone	1A	1B	1L	2A	2B	3	4A	4C	5A	6	6B	7	10A	10B	11	12	13	14
1A	a	a				b	a	a	a	b	b	b	b	b	b	b	b	b
1B	a	a				b	a	a	a	b	b	b	b	b	b	b	b	b
1L	a	a	a			b	a	a	a	b	b	b	b	b	b	b	b	b
2A				a	b													
2B				a	a													
3	a	a				a	a	a	a	b	b	b	b	b	b	b	b	b
4A	b	b				b	a	a	b	b	b	b	b	b	b	b	b	b
4C	b	b				b	a	a	b	b	b	b	b	b	b	b	b	b
5A	b	b				b	b	b	a	b	b	b	b	b	b	b	b	b
6	a	a				a	a	a	a	a	a	a	a	a	a	a	a	a
6B	a	a				b	a	a	a	b	a	b	b	b	b	b	b	b
7	a	a				a	a	a	a	b	a	a	b	b	a	a	a	a
10A	a	a				a	a	a	a	a	a	a	a	a	a	a	a	a
10B	a	a				a	a	a	a	a	a	a	a	a	a	a	a	a
11	a	a				a	a	a	a	b	a	a	b	b	a	a	a	a
12	a	a				a	a	a	a	b	a	a	b	b	a	a	a	a
13	b	b				b	b	b	b	b	b	b	b	b	b	b	a	b
14	b	b				b	b	b	b	b	b	b	b	b	b	b	b	a

Note : Trade of allocation and entitlement is permitted within trading zones 4B, 5B, 9A and 9B, but not to or from these trading zones.

Trading capability for Werribee water system

From Trading Zone (columns); To Trading Zone (rows)

Zone	31AD	31AR	31C	31BD	31BR
31AD	a	a		b	b
31AR	a	a		b	b
31C			a	b	b
31BD	a	a	a	a	a
31BR	a	a	a	a	a

Trading capability for Thomson/Macalister water system

From Trading Zone (columns); To Trading Zone (rows)

Zone	41A	41B	42A	42B
41A	a	a	a	a
41B	a	a	a	a
42A			a	
42B	b	b	a	a

Figure 8: Victorian and southern NSW water trading zones and trading capability (DSE 2011).

Table 16: Victorian and southern NSW trading rules summary (trading zones relevant to the Gunbower are highlighted)

Into trading zone:	Zones	From trading zone:															
		1A Greater Goulburn	1B Boort	1L Loddon Weir Pool	3 Lower Goulburn	4A Campaspe	4C Lower Campaspe	5A Loddon	6 Vic. Murray: Dartmouth - Barmah	6B Lower Broken Creek	7 Vic. Murray: Barmah to S.A.	10A NSW Murray above Barmah	10B Murray Irrigation Limited	11 NSW Murray below Barmah	12 South Australian Murray	13 Murrumbidgee	14 Lower Darling
1A	Greater Goulburn	■	■		□	■	■	■	□	□	□	□	□	□	□	□	□
1B	Boort	■	■		□	■	■	■	□	□	□	□	□	□	□	□	□
1L	Loddon Weir Pool	■	■	■	□	■	■	■	□	□	□	□	□	□	□	□	□
3	Lower Goulburn	■	■		■	■	■	■	□	□	□	□	□	□	□	□	□
4A	Campaspe	□	□		□	■	■	□	□	□	□	□	□	□	□	□	□
4C	Lower Campaspe	□	□		□	■	■	□	□	□	□	□	□	□	□	□	□
5A	Loddon	□	□		□	□	□	■	□	□	□	□	□	□	□	□	□
6	Vic. Murray -Dartmouth to Barmah	■	■		■	■	■	■	■	■	■	■	■	■	■	■	■
6B	Lower Broken Creek	■	■		□	■	■	■	□	■	□	□	□	□	□	□	□
7	Vic. Murray – Barmah to South Australia	■	■		■	■	■	■	□	■	■	□	□	■	■	■	■
10A	NSW Murray above Barmah	■	■		■	■	■	■	■	■	■	■	■	■	■	■	■
10B	Murray Irrigation Limited	■	■		■	■	■	■	■	■	■	■	■	■	■	■	■
11	NSW Murray below Barmah	■	■		■	■	■	■	□	■	■	□	□	■	■	■	■
12	South Australian Murray	■	■		■	■	■	■	□	■	■	□	□	■	■	■	■
13	Murrumbidgee	□	□		□	□	□	□	□	□	□	□	□	□	□	■	□
14	Lower Darling	□	□		□	□	□	□	□	□	□	□	□	□	□	□	■

■ Entitlement and allocation trade □ Allocation (no entitlement) trade up to the volume of back-trade to date

All trade, except to unregulated tributaries, is carried out with an exchange rate of 1.00. Trade (of allocation or entitlement) into Murray Irrigation Limited areas (Zone 10B) attracts a 10 per cent loss of share volume.

Permanent trade is currently limited to four per cent per year from irrigation districts in Victoria. Goulburn-Murray Water advises via media releases when these limits are reached for individual irrigation districts. There are various exemptions for this limit specified in the trading rules on the Victorian Water Register. For more information on water-trading rules, see the Victorian Water Register <http://waterregister.vic.gov.au/>.

A service standard for allocation trade processing times has been implemented by the Council of Australian Governments (COAG):

- Interstate—90 per cent of allocation trades between NSW/Victoria processed within 10 business days.
- Interstate—90 per cent of allocation trades to/from South Australia processed within 20 business days.
- Intrastate—90 per cent of allocation trades processed within five business days.

This means that environmental water holders must make any allocation trades well in advance of a targeted run-off event.

Water trading attracts water-trading fees, without the use of a broker the fees are currently less than $80 in Victoria and $150 in NSW. See the Victorian Water Register for Victorian fee schedules <http://waterregister.vic.gov.au/Public/ApplicationFees.aspx> or State Water <http://statewater.com.au/Customer+Service/Water+Trading>, for fees in NSW.

6.3.2 6.3.2 Water-storage accounting

Water-storage accounting for the Victorian Murray system is annual water accounting (July to June) with some carryover.

In the Victorian Murray, unlimited storage carryover is allowed, but water above 100 per cent of the water-share volume can be quarantined in a spillable water account when there is risk of spill. Any carryover in the spillable water account cannot be accessed until the risk of spill has passed. If a spill occurs, carryover is the first to spill. Annual deduction for evaporation is 5 per cent of the carried-over volume. The fee for transferring water from the spillable water account back to the allocation bank account is $4.52/ML for the Murray system. Goulburn-Murray Water has more information on this <http://www.g-mwater.com.au/customer-services/carryover#1>, and on carryover <http://www.g-mwater.com.au/customer-services/carryover/lbbcarryover/>. DSE is currently reviewing these arrangements.

In the NSW Murray, water allocated against regulated river (high security) access licences and regulated river (conveyance) access licences cannot be carried over.

For regulated river (general security) access licences in the Murray water source, up to 50 per cent may be carried over. These carryover rules are based on the Water Sharing Plan for the NSW Murray and Lower Darling regulated rivers water sources.

7. Risk assessment and mitigation strategies

The environmental watering options outlined in this document (section 3) present a number of risks which require assessment, monitoring and, in some cases, mitigation. Risks associated with the delivery are summarised below and in Table 17 - it should be noted that risks are not static and require continual assessment to be appropriately managed. Changes in conditions will affect the type of risks, the severity of their impacts and the mitigation strategies that are appropriate for use. As such, a risk assessment must be undertaken prior to the commencement of each water delivery with regards to the specific details of the water-use action and the ambient conditions. A framework for assessing risks has been developed by SEWPaC and is included at Appendix 4.

7.1 Blackwater events

Blackwater events can occur within the Gunbower Forest and affect water quality in the Murray River downstream when organic debris on the floodplain is inundated. Decomposition of leaves, bark, wood and other organic matter consumes oxygen, creates anoxic conditions and releases tannins which colour the water. Anoxia persists where there are high organic loads and high concentrations of decomposing microbes, and can result in fish kills. Blackwater conditions are more likely to occur when water temperatures are high (summer and early autumn) and where there is poor water circulation. Blackwater developed in Gunbower Creek and Gunbower Forest in the spring and summer of 2010, and may have been exacerbated by the presence of a very high load of organic matter which had accumulated during the recent drought (Gigney et al. 2006, Howitt et al. 2007). Conditions were intensified by the development of blackwater in water flowing into Gunbower Forest (blackwater extended from Barmah Forest to Torrumbarry Weir and included the lower Goulburn River). Conditions for blackwater development occur in the lower reach of Gunbower Creek, between Koondrook Weir and the Murray River, where water is backed up from a rising Murray River level, but there is no through-flow (M Tranter (North Central CMA) 2011, pers. comm. February 2011).

Watering options that promote floodplain inundation potentially result in blackwater events. However, they may, in the long term, mitigate blackwater by providing more frequent flooding and reducing the accumulation of organic matter to those levels reached in early 2010.

The options to limit blackwater development are limited. Floodplain inundation in warm summer and autumn months should be avoided. Environmental water releases would be unlikely to dilute large events.

7.2 Pest plants and animals

Floodplain inundation supports increased fish breeding, including non-native species. Of particular concern is common carp and oriental weather loach (King et al. 2007, Ecological Associates 2010). The benefits of floodplains to native fish recruitment are significant, and are considered to outweigh the threat posed by pest species. There is little to distinguish the flooding preferences of exotic and native species and no mitigation measures are available for environmental watering options.

A number of aquatic pest plants are present in Gunbower Creek and may spread as a result of environmental watering options (Ecological Associates 2010). Pest plants of concern are:

- white waterlily (*Nymphaea alba*)
- parrots feather (*Myriophyllum aquaticum*)
- willow (*Salix* spp.)
- arrowhead (*Sagittaria platyphylla*).

These plants benefit from inundation and may spread in the forest. The plants will benefit from the higher inundation frequency outlined in this document, however, this would also occur if a natural flow regime were restored to the River Murray. The use of Gunbower Creek as the source of water for the forest does represent an incremental risk for the water use options in this document as the creek is a significant source of propagules of these weeds. The North Central CMA and G-MW are investigating weed management in Gunbower Creek.

Lippia (*Phyla canescens*) is an invasive perennial herb which forms a ground cover in the river red gum woodland and forest understorey and can out-compete native plant species. The weed is not yet widely established in Gunbower Forest and will be monitored by the North Central CMA (Ecological Associates 2010).

7.3 Fish breeding false starts

The breeding of several native fish species is known to be initiated by rising water levels or increased flow in the winter–spring period. It has been suggested that fish-breeding triggers are harmful to fish populations when they cause fish to invest resources in breeding, through migrating or spawning, but do not provide flow conditions to sustain successful recruitment. This may occur if water levels fall too soon after breeding is initiated and juvenile fish do not have access to suitable nursery habitat.

False starts may occur in Gunbower Forest as flow management is shared between irrigation water supply and environmental objectives. Environmental releases to forest watercourses from Hipwell Road in spring may initiate breeding, but may then be reduced and interrupt breeding as irrigation demand on Gunbower Creek reduces capacity for environmental flows.

The severity of this hazard is unclear. It has been identified on the basis of known fish biology, but may not eventuate. Monitoring data is required to determine whether unplanned flow variations significantly compromise native fish breeding objectives.

This risk may be managed by the purchase of a delivery share on Gunbower Creek which would allow the reliable delivery of water to the forest during periods of high irrigation demand.

7.4 Interrupted waterbird breeding

Waterbirds generally require floodwater to be present below or near nesting sites to continue breeding. If floodwaters fall rapidly during a breeding event, birds can leave their nests prematurely, abandoning eggs and leaving chicks to die. This represents a significant energy cost to birds which have invested resources in breeding but failed to recruit a new generation of birds.

Nest abandonment is a risk at Gunbower Forest because the discharge capacity in Gunbower Creek required to maintain forest inundation, cannot be guaranteed when the irrigation season begins on 15 August. As irrigation demand increases, inflows to the forest will be reduced and potentially result in a rapid reduction in forest inundation.

This risk has been assessed by the North Central CMA and is considered significant but acceptable (Ecological Associates 2010). Irrigation demand is low in early spring and it should be possible in most circumstances to continue to provide high inflows and maintain extensive forest inundation into spring so that birds can complete breeding. It is expected that a peak in forest inundation in August or September will initiate breeding. A gradual reduction in inflows over spring will match the hydrograph of natural flooding events and will accommodate irrigation demand. Sufficient capacity to provide moderate inflows of 300 ML/d is likely to be available throughout summer although higher flows will be problematic.

7.5 Giant rush invasion of wetlands

Giant rush *(Juncus ingens)* is a native emergent aquatic plant endemic to Gunbower Forest and the mid-Murray region. It has emerged as a threat to wetland health in Barmah-Millewa Forest where it has been promoted by summer flooding that has increased following river flow regulation. Giant rush has formed extensive, dense beds and excludes other native plant species.

Summer watering will be increased as part of the watering strategy for Gunbower Forest to meet breeding objectives for fish and waterbirds. It is possible these conditions will also favour giant rush establishment in permanent and semi-permanent wetlands.

There are few mitigation measures available for this risk. Watering in summer should be avoided except where clear ecological objectives are being met. Flooding in autumn should be avoided. Deep watering in winter and spring should be provided to reduce giant rush condition.

7.6 River red gum encroachment in wetlands

Open water habitat is an important habitat component for a number of fish and waterbirds but can be threatened by river red gum invasion. River red gums germinate on muddy soil in spring and summer and have become established on the bed of many formerly open wetlands in the recent drought.

River red gum invasion of wetlands in Gunbower Forest may potentially occur as managed flooding events recede. This risk is considered low because in general, permanent and semi-permanent wetlands will remain inundated during the germination period of river red gums and only the river red gum forest and woodland habitat will be exposed over the spring–summer period.

This risk may be mitigated by:

- providing deep watering of wetlands in winter and spring to stress or kill encroaching river red gum seedlings and saplings
- avoiding exposure of the bed of semi-permanent and permanent wetlands in the period from October to January.

7.7 Salinity

The aquifer has a poor connection with the Murray River in this reach. The river surface downstream of Torrumbarry Weir lies approximately eight metres above the water table, indicating that any recharge to the aquifer is strongly constrained. The risk of saline groundwater being mobilised by increased forest inundation and discharging to the Murray River, is considered low (Ecological Associates 2010).

The risk of salinisation along Gunbower Creek has been considered (Ecological Associates 2010). The delivery of flows of 1,650 ML/d via Gunbower Creek to Hipwell Road requires modifications to the creek channel. To provide the higher flow, the creek will be operated 0.5 metres higher at the off-take. The higher hydraulic gradient from the creek to the surrounding landscape potentially creates water logging and salinisation in the adjacent land.

Any increase in current levels of seepage and leakage will relate to the time Gunbower Creek is operated significantly higher than current levels. The water use options involve Gunbower Creek operating 0.5 metres higher than current levels for up to:

- 46 days in the dry scenario
- 61 days in the median scenario
- 107 days in the wet scenario.

The risk from raised water levels in Gunbower Creek is considered very low (Ecological Associates 2010).

7.8 Acid sulfate soils

Exposure of acid-forming soils to air can cause acidification which, when the soils are inundated, reduces their pH and mobilises minerals toxic to plant and animal life. Gunbower Forest is considered a low risk for acid sulfate soils as the water table is low and there are currently very limited areas subject to waterlogging. Permanently flooded lagoons on Gunbower Creek have been evaluated and provide a moderate risk of acid sulfate soil development (SMEC 2010).

Table 17: Risks associated with water delivery in the Gunbower Forest

Risk type	Likelihood	Consequence	Risk level	Mitigation strategies
Blackwater events	Likely	Moderate	Medium	Blackwater risks may be reduced by: • providing recommended floodplain inundation regimes that avoid sustained periods without inundation • minimising floodplain inundation in warm summer months • providing environmental water to provide dilution flows within the forest and river when blackwater events occur.
Aquatic pest plants	Likely	Major	High	Control the source of pest plants in Gunbower Creek.
Pest fish	Likely	Major	High	No control methods are practicable. Impacts will be exceeded by benefits to native flood-dependent flora and fauna.
Fish-breeding false-starts	Possible	Minor	Low	Minimise sudden decreases in inflows during the spring–summer period.
Interrupted waterbird breeding	Possible	Moderate	Medium	Minimise sudden decreases in inflows during the spring–summer period.
Giant rush invasion of wetlands	Possible	Moderate	Medium	Provide recommended deep wetland watering in winter–spring. Minimise inundation of wetland emergent plant zones in summer and autumn.
River red gum encroachment in wetlands	Possible	Moderate	Medium	Provide recommended deep wetland watering in winter–spring.
Salinity	Unlikely	Minor	Low	None required.
Acid sulfate soils	Unlikely	Moderate	Low	None required.

8. Environmental water reserves

8.1 Environmental water holdings and provisions

8.1.1 Water planning responsibilities

The Northern Region Sustainable Water Strategy (NRSWS) provides the strategic direction for water management across Northern Victoria (DSE 2009). The NRSWS also presents the community target for the agreed level of health for waterways and environmental assets, which the Victorian Government has agreed to try and meet through various mechanisms including seeking water from the Commonwealth Environmental Water Office. Responsibilities for the planning and delivery of water under Victorian environmental entitlements in the Murray River and Gunbower Creek are managed by the Victorian Environmental Water Holder in conjunction with the North Central CMA. Goulburn-Murray Water has responsibility for the operation of the Torrumbarry Irrigation Area. Forest regulators in Victoria are controlled by Goulburn-Murray Water under the direction of the MDBA and operated by the DSE.

The Water Sharing Plan for the NSW Murray and Lower Darling Regulated Rivers Water Sources governs water management in the NSW Murray River. Water sharing is administered by the NSW Office of Water. The adaptive environmental water allocated under the water sharing plan is overseen by the NSW Office of Environment and Heritage (OEH). OEH prepares an adaptive environmental water plan for the Murray Valley each year. During the 2009-10 season, the Murray Lower Darling Environmental Water Advisory Group (MLD EWAG) was established to provide advice on the management of environmental water within the NSW Murray Valley. This includes representatives from the Murray CMA and State Water. Forest regulators in NSW are controlled by OEH under the direction of the MDBA and operated by NSW State Forests.

8.1.2 Environmental water provisions

Minimum flow requirements are not specified in the Water Sharing Plan for the NSW Murray and Lower Darling Regulated Rivers Water Sources. Rather, a volume of water is allocated to the environment as part of the adaptive environmental water allowance in the plan. The volume of the adaptive environmental water allowance is listed in Table 19. Similarly, the Victorian environmental water entitlements do not specify minimum channel flows in the Murray River.

During the irrigation season, flows in the Murray River and Gunbower Creek are generally running above natural stream flows to supply irrigation deliveries. During the non-irrigation season, minimum flows in the Murray River are provided from Victorian tributaries.

Minimum flows from Victorian tributaries downstream of Barmah-Millewa Forest are outlined in the respective Environmental Water Delivery documents for the Goulburn River and Campaspe River. This includes:

- minimum flows in Goulburn-Murray Water's Goulburn River bulk entitlement, which requires any additional flow from the Goulburn River necessary to maintain a minimum average monthly flow at the McCoys Bridge gauging station of 350 ML/d for the months of November to June (at a daily rate of no less than 300 ML/d) and 400 ML/d for the months of July to October inclusive (at a daily rate of no less than 350 ML/d)
- minimum flows of 35–70 ML/d in the Campaspe River from Campaspe Siphon to the Murray River, as specified in Goulburn-Murray Water's Campaspe System bulk entitlement
- no minimum flows specified for Broken Creek outflows, however flows are often delivered along Broken Creek to manage water quality.

While not specified in the water sharing plan or environmental entitlements, minimum Murray River flows are maintained for operational purposes. Downstream of Yarrawonga Weir a minimum flow of 1,800 ML/d is maintained "to provide minimum flows for riparian and water quality requirements" (MDBA 2010c). When releases from Yarrawonga Weir drop below 4,000 ML/d irrigation diverters at Moira Lake are affected. When flows at Tocumwal drop below 6,000 ML/d, the Bullatale Creek irrigators who access water from Lower Toupna Creek can be affected (MDBA 2010c). The MDBA notifies these parties if minimum flows drop below these values, which suggests flows are generally maintained above these values during the irrigation season.

Minimum flow requirements downstream of Torrumbarry Weir in the Murray River operations manual are unclear. A minimum flow of 1,800 ML/d is suggested to provide flows for riparian and water quality requirements (MDBA 2010c) and higher minimum flows for navigation of the weir.

8.1.3 Current water holdings

Commonwealth environmental water holdings (as at October 2010) in the southern Murray-Darling connected system are summarised in Table 18. Entitlements have been identified separately upstream and downstream of the Barmah Choke, as there can sometimes be a restriction on trade. Trading of allocations to and from the Murray system can occur subject to the allocation trading rules previously outlined in Section 6 of this document. The volume held by the Commonwealth Environmental Water Holder in the southern Murray-Darling Basin (as at October 2010) includes up to 194,000 ML upstream of the Barmah Choke and 308,000 ML downstream of the Barmah Choke. The entitlement register is updated regularly and can be accessed at http://www.environment.gov.au/ewater/about/holdings.html.

Table 18: Licence volumes currently held by the Australian Government (as at October 2010)

System	General security/low reliability (ML)	High security/reliability (ML)
NSW Murray above Barmah Choke	155,752.0	0.0
VIC Murray above Barmah Choke	5,674.1	32,361.3
Ovens[a]	0.0	
Total above Barmah Choke	**161,426.1**	**32,361.3**
NSW Murray below Barmah Choke	32,558.0	386.0
VIC Murray below Barmah Choke	5,451.3	78,721.9
Murrumbidgee[b]	64,959.0	
Goulburn	10,480.0	64,919.6
Broken River [c]	0.0	
Campaspe	395.4	5,124.1
Loddon	527.3	1,179.0
South Australia		43,297.4
Total below Barmah Choke	**114,371.0**	**193,628.0**

a Commonwealth environmental water holdings include 70 ML of regulated river entitlement on the Ovens system. This water cannot be traded outside of the Ovens basin.

b Commonwealth environmental water holdings include 20,820 ML of supplementary water shares on the Murrumbidgee system. This water cannot be traded out of the Murrumbidgee system.

c Commonwealth environmental water holdings include 20 ML of high reliability water share and 4.2 ML of low reliability water share in the Broken River system. This water cannot be traded out of the Broken basin.

Environmental water shares held by other agencies in the NSW and Victorian Murray River downstream of the Choke are listed in Table 19. Only volumes downstream of the Choke have been listed as other water shares are generally tied to use at specific locations. This table indicates that up to 680,000 ML could be available from other environmental water entitlements in the Murray River downstream of the Choke in a wet year. This does not include environmental water delivered to Barmah Forest and along the Goulburn River, which can potentially contribute several hundred gigalitres more to the Murray River at Torrumbarry Weir.

Table 19: Environmental water currently held by other agencies in Victorian and NSW Murray River downstream of Barmah Choke

Water holding	Volume	Comments
Water Sharing Plan for the NSW Murray and Lower Darling Regulated Rivers Water Sources **Adaptive Environmental Water**	30,000 unit shares conveyance (broadly equivalent to ~15,000 ML high security and ~15,000 ML low security) 2,027 unit shares high security (~2,000 ML)	
Water Sharing Plan for the NSW Murray and Lower Darling Regulated Rivers Water Sources **Murray Additional Environmental Allowance**	0.03 ML per unit share of high security (~6,000 ML)	
Murray River—Flora and Fauna Conversion Further Amending Order (2009) (Victoria)—**Flora and Fauna**	27,600 ML high reliability	
Murray River—Flora and Fauna Conversion Further Amending Order (2009) (Victoria)—**The Living Murray**	2,080 ML high reliability 58,537 ML low reliability 34,300 ML unregulated flow	Unregulated flow entitlement only available when MDBA declares its availability.
The Living Murray—NSW Murray system	1,887 high security 134,387 general security 350,000 ML supplementary 12,965 ML unregulated	

8.2 Seasonal allocations

Forecasting water availability will enable environmental water managers to prioritise the delivery of flow recommendations for the coming season from available allocations.

Victorian allocations are announced by Goulburn-Murray Water every month <http://www.nvrm.net.au/allocations/current.aspx>.

NSW State Water calculates available water determinations every month, which are then confirmed and issued by OEH <http://www.water.nsw.gov.au/Water-Management/Water-availability/Available-water-determinations/default.aspx>, while a register of historical announcements is listed at <http://www.wix.nsw.gov.au/wma/DeterminationSearch.jsp?selectedRegister=Determination>.

Long-term seasonal allocations for the Murray River are shown for October and April as indicative of spring and autumn in Figure 9 and Figure 10. This information is sourced from the MSM-Bigmod post-TLM run (#22061). These figures indicate that full high and low-security volume is provided by October in just under 50 per cent of years. Long-term seasonal allocations for the Goulburn and Campaspe systems (upstream tributary systems) are shown in Appendix 3.

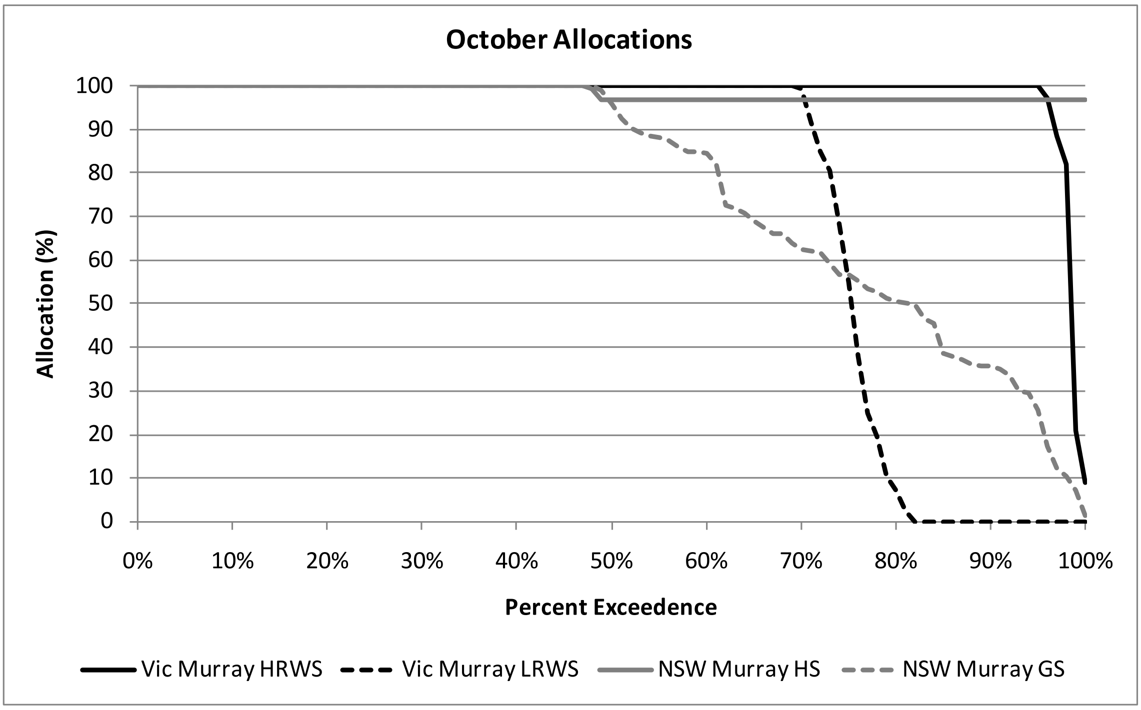


Figure 9: October seasonal allocations for the Murray system

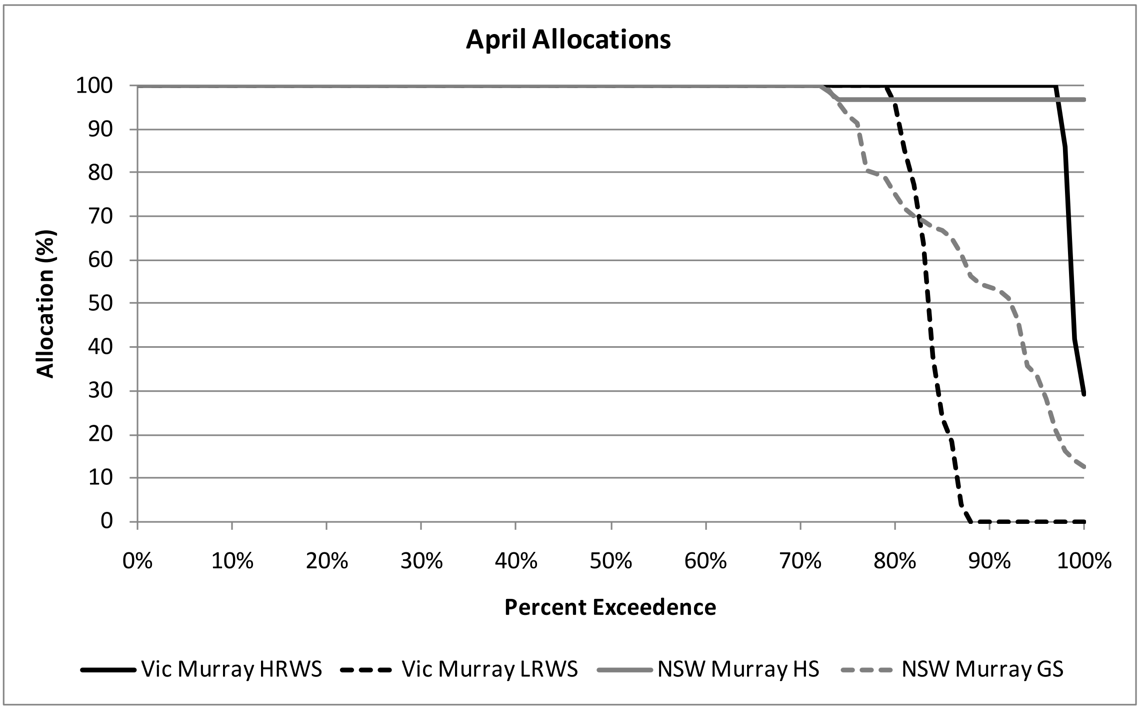


Figure 10: April seasonal allocations for the Murray system

The allocation percentages expected to be available under different water scenarios are summarised in Table 20. The corresponding volumes of water (based on October 2010 holdings) are summarised in Table 21. This table shows, for example, that environmental water holders could expect to have in the order of 9 per cent of Victorian high-reliability water shares available in spring in a very dry year (based on October 2010 holdings this equates to 2,900 ML above the Choke and 7,100 ML below the Choke). In a wet year, water availability would increase to 100 per cent of both high and low-reliability water shares. If water is traded from other locations within the connected southern Murray-Darling Basin, then up to 53,000 ML could be available in spring in a very dry year and up to 502,000 ML could be available in spring in a wet year (based on October 2010 holdings), subject to any trading constraints.

A new reserve policy was introduced for the Goulburn system in 2010–11 and is planned for the Victorian Murray system in 2012–13. The new reserve policy may improve allocations (and hence water availability for the environment) in very dry years but may reduce allocations in some dry years. The impact of the new reserve policy is not included in the modelling, and hence is not included in the assessment of the allocation and volume of water expected to be available to environmental water holders under different climate conditions.

Table 20: Likely allocation percentages

River System	Security	Registered Entitlements (ML) (Oct 2010)	Water Availability							
			October Allocation (%)				April Allocation (%)			
			Very Dry	Dry	Median	Wet	Very Dry	Dry	Median	Wet
NSW Murray above Barmah Choke	General Security	155,752.0	1	62	96	100	12	100	100	100
Victorian Murray above Barmah Choke	High reliability water share	32,361.3	9	100	100	100	29	100	100	100
	Low reliability water share	5,674.1	0	99	100	100	0	100	100	100
Ovens	High reliability water share	70.0	100	100	100	100	100	100	100	100
NSW Murray below Barmah Choke	High security	386.0	97	97	97	100	97	100	100	100
	General Security	32,558.0	1	62	96	100	12	100	100	100
Victorian Murray below Barmah Choke	High reliability water share	78,721.9	9	100	100	100	29	100	100	100
	Low reliability water share	5,451.3	0	99	100	100	0	100	100	100
Murrumbidgee	General Security	64,959.0	10	42	55	64	10	68	100	100
	Supplementary	20,820.0	0	0	0	100	0	0	0	100
Goulburn	High reliability water share	64,919.6	20	100	100	100	28	100	100	100
	Low reliability water share	10,480.0	0	4	54	96	0	17	78	100
Broken	High reliability water share	20.0	1	96	97	98	1	100	100	100
	Low reliability water share	4.2	0	0	0	0	0	100	100	100
Campaspe	High reliability water share	5,124.1	33	100	100	100	43	100	100	100
	Low reliability water share	395.4	0	100	100	100	0	100	100	100
Loddon	High reliability water share	1,179.0	0	100	100	100	0	100	100	100
	Low reliability water share	527.3	0	2	54	96	0	16	78	100
South Australia	High reliability	43,297.4	44	100	100	155	62	100	100	102

Table 21: Likely volumes available to the environment from Commonwealth entitlements

River System	Security	Registered Entitlements (ML) (Oct 2010)	Water Availability							
			October Allocation (GL)				April Allocation (GL)			
			Very Dry	Dry	Median	Wet	Very Dry	Dry	Median	Wet
NSW Murray above Barmah Choke	General Security	155,752.0	2.2	97.2	149.1	155.8	19.3	155.8	155.8	155.8
Victorian Murray above Barmah Choke	High reliability water share	32,361.3	2.9	32.4	32.4	32.4	9.4	32.4	32.4	32.4
	Low reliability water share	5,674.1	0.0	5.6	5.7	5.7	0.0	5.7	5.7	5.7
Ovens*	High reliability water share	70.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total above Barmah Choke			**5.1**	**135.2**	**187.2**	**193.8**	**28.7**	**193.8**	**193.8**	**193.8**
NSW Murray below Barmah Choke	High security	386.0	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4
	General Security	32,558.0	0.5	20.3	31.2	32.6	4.0	32.6	32.6	32.6
Victorian Murray below Barmah Choke	High reliability water share	78,721.9	7.1	78.7	78.7	78.7	22.8	78.7	78.7	78.7
	Low reliability water share	5,451.3	0.0	5.4	5.5	5.5	0.0	5.5	5.5	5.5
Murrumbidgee*	General Security	64,959.0	6.5	27.3	35.7	41.6	6.5	44.2	65.0	65.0
	Supplementary	20,820.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Goulburn	High reliability water share	64,919.6	13.0	64.9	64.9	64.9	18.2	64.9	64.9	64.9
	Low reliability water share	10,480.0	0.0	0.4	5.7	10.0	0.0	1.8	8.2	10.5
Broken*	High reliability water share	20.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Low reliability water share	4.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Campaspe	High reliability water share	5,124.1	1.7	5.1	5.1	5.1	2.2	5.1	5.1	5.1
	Low reliability water share	395.4	0.0	0.4	0.4	0.4	0.0	0.4	0.4	0.4
Loddon	High reliability water share	1,179.0	0.0	1.2	1.2	1.2	0.0	1.2	1.2	1.2
	Low reliability water share	527.3	0.0	0.0	0.3	0.5	0.0	0.1	0.4	0.5
South Australia	High reliability	43,297.4	19.0	43.3	43.3	66.9	26.6	43.3	43.3	44.3
Total below Barmah Choke			**48.1**	**247.4**	**272.3**	**307.7**	**80.8**	**278.1**	**305.6**	**309.0**
Total			**53.2**	**382.6**	**459.5**	**501.5**	**109.5**	**471.8**	**499.4**	**502.8**

* Commonwealth holdings on the Ovens and Broken system and supplementary holdings on the Murrumbidgee system cannot be traded outside of the source trading zone. As such, holdings in these basins do not contribute to total water availability.

8.3 Water availability forecasts

A description of likely water availability for the Victorian Murray System is provided by Goulburn-Murray Water when allocation announcements are made. Allocation announcements are generally made on the 15th of each month (or the next business day), however, when allocations to high-reliability water shares are less than 100 per cent allocations announcements are made on the 1st and 15th of each month (or the next business day).

The current allocation announcement and a description of likely future water availability for the remainder of the season can be sourced from Goulburn-Murray Water <http://g-mwater.com.au/news/allocation-announcements/current.asp>, as can historical announcements and forecasts <http://g-mwater.com.au/news/allocation-announcements/archive.asp>. Additionally, Goulburn-Murray Water publishes a seasonal allocation outlook prior to the start of each irrigation season providing a forecast for opening, October and February allocations for the following season <http://www.g-mwater.com.au/mews/media-releases>.

For the NSW Murray, in recent years the Office of Water has provided regular "critical water planning communiqués" during periods of exceptional circumstances. Examples of these communiqués <http://www.water.nsw.gov.au/Water-Management/Water-availability/Critical-water-planning/default.aspx> include the probability of certain storage volumes being reached later in the season and how this could affect allocations. After October 2010, publication of critical water-planning communiqués ceased due to improved water availability.

Under normal conditions the Office of Water provides allocation announcements for the NSW Murray via media releases on the 1st and 15th of each month along with key information concerning water management and availability <http://www.water.nsw.gov.au/Water-management/Water-availability/Water-allocations/Available -water-determinations/default.aspx>.

PART 3:
Monitoring and future options

9. Monitoring evaluation and improvement

9.1 Existing monitoring programs and frameworks

A range of monitoring methods are used to assess the physical environment and ecosystem condition of Gunbower Forest. Three monitoring programs that have been established under the TLM Outcomes Evaluation Framework are:

- Murray River system-scale annual monitoring which measures changes in ecological condition across the Murray River system in relation to fish, waterbirds and vegetation.
- Icon site condition monitoring to assess condition in relation to Icon Site objectives (Table 22).
- Intervention monitoring, which investigates links between environmental watering, works and measures and ecological outcomes. Intervention monitoring targets environmental watering events that will inform key knowledge gaps or ecological questions.

Table 22: Icon Site condition monitoring components for Gunbower Forest (DSE 2009)

Component	Monitoring Approach
Vegetation—wetland	Wetlands assessments
Vegetation—overstorey	River red gum and black box stand condition
	River red gum and black box tree condition
Vegetation—understorey	Understorey vegetation assessment
Birds	Quarterly on-ground waterbird assessments
	Colonial and other waterbird monitoring surveys
	Annual aerial waterbird survey
	Bush bird fixed monitoring sites
Fish	Assessment of the fish community
	Resident fish survey
Frogs	Frog abundance and diversity
	Tadpole sampling

Other existing programs with relevant monitoring components include the Sustainable Rivers Audit, Native Fish Strategy and Natural Resources Information.

9.2 Flow monitoring sites

There are various measuring points for environmental water relevant to the Gunbower Forest, as listed in Table 23. This includes a combination of streamflow monitoring along the Murray River and from the main tributaries downstream of Lake Hume, and flow and water-level monitoring into and out of the forest. Real-time data is available from the MDBA <http://www.mdba.gov.au/water/live-river-data/yarrawonga-to-euston> for main Murray River sites, with more detailed information also available <http://waterinfo.nsw.gov.au/>. Historical data and maps of site locations are also available <http://www.dse.vic.gov.au/waterdata/>. Goulburn-Murray Water collects operational flow data for the Torrumbarry system and storage volume data for the headworks storages.

Table 23: Flow monitoring in the Murray River near Gunbower Forest

Site number	Site name	Relevance to this document
409016	Murray River at Heywoods	Flows from Lake Hume
402205	Kiewa River at Bandiana	Flows from Kiewa River
409017	Murray River at Doctors Point	Flows in Murray River downstream of Kiewa River
403241	Ovens River at Peechelba East	Flows from Ovens River
409025	Murray River d/s Yarrawonga	Flows downstream of Yarrawonga Weir
409006	Murray River at Picnic Point	Flows through the Barmah Choke downstream of Gulpa Creek
404210	Broken Creek at Rices Weir	Flows from Broken Creek
409215	Murray River at Barmah	Flows downstream of Barmah-Millewa Forest
405232	Goulburn River at McCoys Bridge	Flows from Goulburn River
406202	Campaspe River at Rochester	Flows from Campaspe River
409219	Murray River at Torrumbarry Weir	Water level and volume in weir pool
409207	Murray River d/s Torrumbarry Weir	Flows downstream of Torrumbarry Weir
409701	National Channel at offtake	Flows diverted to National Channel
407233	Gunbower Creek at Gunbower Weir	Offtake to Gunbower Creek from National Channel
407265	Gunbower Creek at Thompson Weir	Flows in Gunbower Creek mid-forest
409209	Murray River at Cohuna	Flows in Murray River mid-forest
407209	Gunbower Creek at Koondrook	Outflows from Gunbower Creek to Murray River
409005	Murray River at Barham	Murray River downstream of Gunbower Forest

9.3 Operational water delivery monitoring

Water delivery and water use

Water delivery monitoring is required to report how much water was used in an environmental watering event and how it was delivered. This information is required to account for environmental water use and to refine the effectiveness and efficiency of future watering events. Key questions to be addressed include the following:

- How did actual water use compare with planned water use? Can future estimates of water use be improved?
- How well did delivery procedures work? Can releases and regulator operations be improved to increase efficiency, increase effectiveness and reduce undesirable impacts?
- Were there constraints on delivery that affected the watering event?
- Were catchment inflows accommodated?

A template for recording operational water delivery associated with the use of Commonwealth environmental water is provided at Appendix 4 and a summary of monitoring requirements is provided in Table 24.

Environmental water releases to the forest can be readily determined from the discharge at environmental regulators on Gunbower Creek. Rating data is required for each of the regulators and will need to account for water levels downstream and their backwater effects.

Flows returned to the Murray River via Shillinglaws regulator and Barham Cut regulator can be determined by gauging records and rating tables. A new gauge will be installed on Gunbower Creek near Condidorios Bridge which, together with the gauge at Koondrook Weir, will measure forest outfalls. A hydrodynamic model will be used to estimate water use and water use in range of standard scenarios have been developed (Water Technology 2009).

Table 24: Monitoring requirements for environmental water delivery and use

Component	Monitoring approach	Source of information
Planned water use	Refer to event watering plan.	Environmental water holder.
Total volume of water delivered in watering event	Gauged flow at Gunbower Creek environmental regulators. Gauged flow at Koondrook Weir.	Goulburn-Murray Water.
Start date and end date	Goulburn-Murray Water records.	Goulburn-Murray Water.
Structure operations	Times and operation of National Channel, Gunbower Creek, environmental regulators and other structures.	Murray River Operations (oversight). Goulburn-Murray Water (operation).
Environmental water use	Gauged inflows and outflows. Estimate water use by running inflow records for completed events through the hydrodynamic model. Estimate water use from standard flow scenarios using the hydrodynamic model.	Contractors engaged by Murray River Operations and Goulburn-Murray Water (regulator flow measurement). Murray River Operations (data loggers).

Watering Outcomes

The outcomes of environmental watering include the hydraulic conditions that are achieved and the ecological and environmental responses to those conditions.

Gauge boards are located in permanent and some semi-permanent wetlands. At low-to-moderate inundation levels these can be accessed to report water depth. When the forest is flooded extensively these can be difficult to access. The extent of forest submersion created by managed watering events is currently determined by a combination or gauge board monitoring and selective satellite imagery (Table 25).

The depth achieved by watering and the duration of inundation controls the structure of vegetation communities and is central to the ecological and hydrological objectives. There are currently no comprehensive arrangements in place to collect depth-duration data. It could be determined by running the hydrograph through the hydrodynamic model or collecting data directly using depth loggers at representative sites.

Table 25: Monitoring requirements for hydraulic conditions that underpin the ecological objectives set out in Table 3

Hydraulic conditions	Source of information
Extent of inundation: • total area • area of vegetation communities.	1. Forest gauge boards and flood extent assessment. 2. Future routine use of Normalised Difference Vegetation Index or other satellite imagery. 3. Run Murray River hydrograph and regulator inflows through hydrodynamic model.
Depth-duration data: • permanent and semi-permanent wetlands • river red gum with flood-dependent understorey.	1. Read gauges at low-to-moderate inundation levels. 2. Run hydrograph through hydrodynamic model. 3. Install water depth loggers at representative sites.

Existing monitoring programs undertaken for the TLM program address most of the ecological outcomes that the environmental watering options in this document seek to achieve (Table 3 and Table 26).

Wetland vegetation surveys comprise 15 transects located within permanent and semi-permanent wetlands. Data on vegetation structure and composition is collected to report the condition of vegetation. Understorey vegetation surveys collect data from 110 quadrats in a range of vegetation types (river red gum with flood-dependent and flood-tolerant understorey, black box, grey box) and landscape positions (watercourses, river bank, floodplain and wetland). Data is collected in transects and describes changes in the position and extent of the vegetation types as they respond to prevailing water regimes. Data is collected four times each year and reported annually (DSE 2009).

The TLM Stand Condition Model reports the condition of river red gum by combining Landsat data and on-ground measurements of monitoring stands. Data is reported annually (DSE 2009 #2495). In addition, tree condition is assessed on the ground for groups of 30 trees at representative sites using the TLM Tree Condition Assessment (DSE 2009 #2495) (MDBA 2010a,b,c).

Waterbird responses to watering events and overall forest condition are assessed by on-ground and aerial surveys (DSE 2009 #2495) (MDBA 2010a,b,c). The waterbird condition monitoring program is undertaken at quarterly intervals at sites where water is present, and reports the bird species present, their abundance and breeding activity. Additional event-based ground surveys target breeding colonies and report the number of nests, the nesting habitat and the number of fledglings. The aerial survey is undertaken annually to coincide with the annual eastern Australian waterbird survey. The survey reports the abundance of waterbird species and the number of nests and broods (Kingsford & Porter 2008).

Fish monitoring involves a number of components that help evaluate the effects of watering events (DSE 2009 #2495). Fish-condition monitoring reports on the species present, their abundance, size, health and condition. Fish-spawning and recruitment surveys are assessed annually between September and February to target periods of variable flow within the breeding season.

Turtles are not monitored at Gunbower Forest.

Frogs are monitored in at least 20 sentinel sites. Monitoring reports on the abundance of species of adult and tadpole frogs, habitat condition and water quality (DSE 2009 #2495).

Table 26: Monitoring requirements for ecological outcomes of environmental watering

Ecological watering objectives (see Table 3)		Water scenario				Monitoring
		Extreme dry	Dry	Median	Wet	
Vegetation health	Maintain wetland vegetation.	✓	✓	✓	✓	Wetland vegetation survey
	Maintain health of riparian vegetation on forest watercourses.	✓	✓	✓	✓	Understorey vegetation survey
	Maintain river red gum tree health.	×	✓	✓	✓	TLM Stand Condition Model TLM Tree Condition Assessment
	Maintain black box tree health.	×	×	✓	✓	TLM Tree Condition Assessment
Habitat structure	Maintain open water in wetlands.	✓	✓	✓	✓	Understorey vegetation survey
	Provide aquatic habitat below Koondrook Weir.	✓	✓	✓	✓	Gauge downstream of Koondrook Weir
	Maintain river red gum understorey.	×	✓	✓	✓	Understorey vegetation survey
Fish	Provide drought refuge.	✓	×	×	×	Assessment of fish community resident fish survey
	Fish migration and dispersal.	✓	✓	✓	✓	None
	Stimulate fish breeding.	×	✓	✓	✓	Assessment of fish community resident fish survey

Ecological watering objectives (see Table 3)		Water scenario				Monitoring
		Extreme dry	Dry	Median	Wet	
Waterbirds	Provide drought refuge.	✓	×	×	×	Quarterly on-ground waterbird assessments Annual aerial waterbird survey
	Provide forest feeding habitat for waterbirds.	×	✓	✓	✓	Waterbird Condition Monitoring—ground survey
	Support waterbird breeding.	×	✓	✓	✓	Census in wetland perimeter transects Colonial and other water waterbird assessment – aerial survey
Organic matter	Inundate organic matter in winter and spring to reduce summer blackwater risks.	×	✓	✓	✓	See Table 25 above
	Export organic matter to Murray River and Edward-Wakool systems.	×	✓	✓	✓	None
Turtles	Provide drought refuge.	✓	×	×	×	None
	Maintain aquatic habitat throughout the year.	×	✓	✓	✓	None
Invertebrates	Provide drought refuge.	✓	×	×	×	None
	Maintain aquatic habitat throughout the year.	×	✓	✓	✓	Invertebrate sampling within frog monitoring

Data to describe environmental water delivery will be readily available from Goulburn-Murray Water operational records for Gunbower Creek. The means to evaluate the net use of water are less clear and will most likely involve the post hoc use of the hydrodynamic model. The extent of inundation within the forest will be determined using gauge boards and satellite imagery. The discharges achieved downstream of Koondrook Weir are currently gauged by Goulburn-Murray Water.

The most important ecological outcomes targeted by the watering options are addressed by existing monitoring arrangements including the structure and composition of vegetation communities and the populations and breeding of fish and waterbirds.

10. Opportunities

10.1 Koondrook Weir fishway and passing flow

Gunbower Creek is managed primarily as an irrigation channel for the Torrumbarry Irrigation Area. The 102-kilometre-long creek diverts regulated water from the Torrumbarry Weir pool on the Murray River via the National Channel and rejoins the River at Koondrook.

The creek provides valuable fish habitat that includes fast-flowing reaches, backwaters, extensive aquatic and woody riparian vegetation and debris and a diversity of channel depths and forms. When the forest regulators are open, Gunbower Creek is connected to Gunbower Forest which increases the extent and variety of habitat available to fish. High flows and managed watering events also provide opportunities for migration and dispersal by fish from Gunbower Creek. The creek has high native fish diversity and supports trout cod, native catfish, Murray cod, silver perch, bony bream and flyspecked hardyhead.

Gunbower Creek is managed by a series of regulators including Gunbower Weir, Thompson Weir, Cohuna Weir and Koondrook Weir. Fish passage is currently provided at the Gunbower and Thompson weirs, and is proposed for the Cohuna Weir. The new mid-forest regulator that will divert water to Gunbower Forest will have a temporary weir on Gunbower Creek.

The movement of fish through Gunbower Creek is important to provide fish with access to all available habitats and to their migration and dispersal requirements. Movement is also important to increase the number of potential refuge populations and to allow fish to avoid unfavourable conditions such as blackwater.

Koondrook Weir is the lowest weir on Gunbower Creek. Under normal conditions all remaining flow is diverted from Gunbower Creek at Koondrook Weir and there is no passing flow to connect Gunbower Creek to the Murray River. Water only connects the reach between Koondrook Weir and the Murray River when the Murray River is rising and water backs up to the weir, or when flow in Gunbower Creek exceeds capacity and must be spilt over the weir, such as in rain rejection events or floods.

Rising river levels create a blackwater hazard as the water backing up towards the weir has low velocity, shallow depths and high organic loads.

A passing flow and fishway may be considered at Koondrook Weir to:

- reduce the risk of blackwater and fish kills in the reach of Gunbower Creek below the weir
- provide fish habitat in the reach of Gunbower Creek below the weir
- provide upstream and downstream migration and dispersal opportunities from Gunbower Creek to the wider Murray River.

10.2 Lower landscape works

TLM works in this area will facilitate filling and topping up wetlands, using relatively small volumes of water.

The proposed infrastructure works include refurbishing existing regulators within the forest, constructing new regulators and decommissioning a single regulator (MDBA 2011b). This will enhance the flexibility to operate at smaller volumes when less water is available. It will also allow for a considerable proportion of water to be returned to the Murray River after the required inundation period (MDBA 2010c).

10.3 Upper Forest Channel

The proposed Upper Forest Channel is designed to deliver water to Gunbower Forest from the Torrumbarry Weir pool. The channel complements other forest regulators by increasing the volume of water that can be delivered to the forest at any given time and by delivering water higher in the forest to inundate additional areas that are not affected by the existing works.

The channel would divert water from above the Torrumbarry Weir and pass through the black box and EPBC-listed grey box woodland of the upper forest. This area of forest includes a highly productive temporary wetland system and supports a complex community of woodland birds. The channel would release water to river red gum and black box woodland near Lock Road and combine with releases from the mid-forest regulator at Hipwell Road to increase the inundated area in the central forest.

At present, the largest available watering option for Gunbower Forest is via the mid-forest regulator (under construction in 2011). The capacity of the regulator is limited to 1,650 ML/d by the capacity of the supply channel (Gunbower Creek). Releases can mimic a natural flow of 38,000 ML/d in the forest, inundating 4,710 hectares. This is less than a quarter of the total forest area and 29 per cent of the river red gum vegetation. However, if the proposed Upper Forest Channel were to be constructed, it would be possible to:

- increase the delivery rate of water to Gunbower Forest to increase the inundation footprint in the central and lower forest
- introduce water higher in the forest to inundate the upper forest and provide connectivity for native fish across the entire length of the forest
- allow the flood requirements of a vegetation community to be met that is not watered by any other options
- inundate an additional 3,000 hectares of forest (allowing managed floods to be delivered to almost 50 per cent of the forest).

10.4 Hipwell Road weir bypass channel 6/1 Channel outfall regulator upgrade

The operation of the mid-forest regulator is constrained by the role of Gunbower Creek as an irrigation supply channel. The regulator diverts almost all available capacity from Gunbower Creek to the forest when it is operating, so that the creek cannot support irrigation diversions. Consequently, the regulator can only be operated in winter until August 15 when the irrigation season starts or, potentially, in early spring in wet years if irrigation demand is low.

The winter operation of the regulator prevents spring floods in the forest, as would have occurred naturally. Many fish and bird species require flooding through spring and into early summer to breed successfully, and the inability to continue releases from the mid-forest regulator represents a risk to these outcomes.

The 6/1 Channel provides an opportunity to introduce additional water to Gunbower Creek below the regulator by delivering flow from above Gunbower Weir via Taylors Creek and the No.1 Channel (Figure 11). At present, the 6/1 Channel is primarily used to release rain rejection flows to Gunbower Creek and has a limited capacity at the outlet regulator. Upgrading the capacity of the bypass would allow winter flows to be maintained in Gunbower Creek when the weir is being operated to flood Gunbower Forest. This would provide greater flexibility in the operation of the mid-forest regulator to maximise environmental outcomes while meeting the needs of irrigation customers.

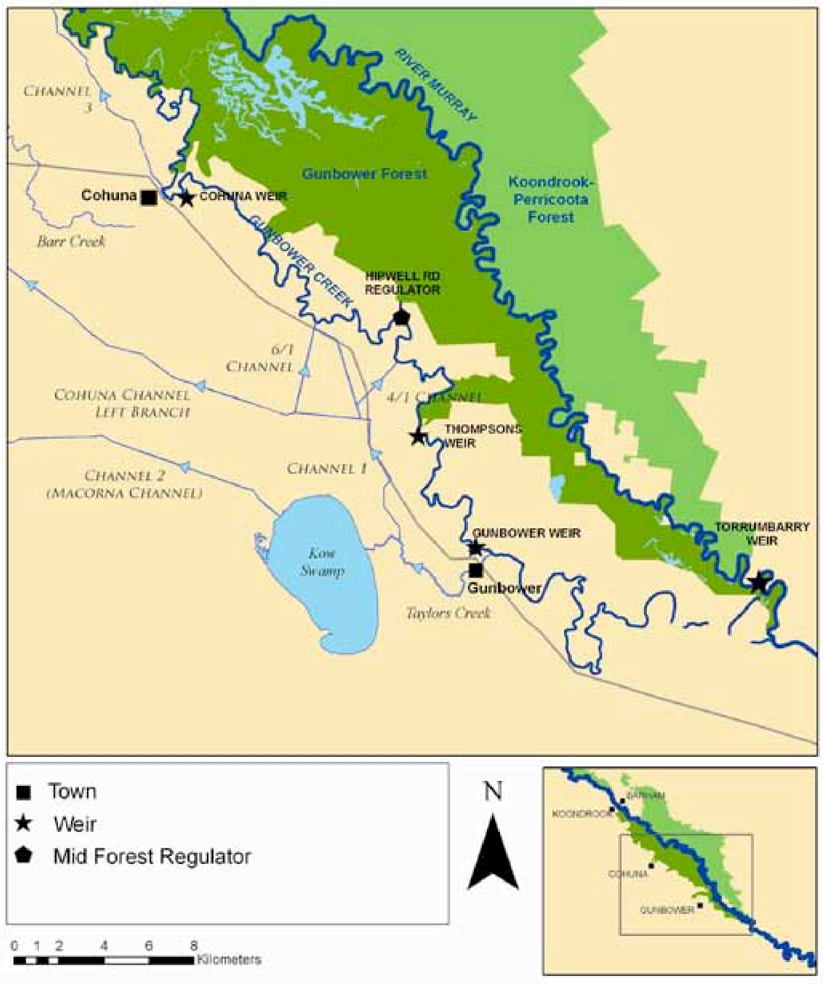


Figure 11: Elements of the Torrumbarry Irrigation Area in relation to the 6/1 Channel

10.5 National Channel fishway

Gunbower Creek receives water from the Murray River via the National Channel. Water is supplied by an undershot weir which provides very limited downstream fish passage and prohibits upstream passage.

A fishway has been proposed at this site to allow upstream fish migration to the Murray River. North Central CMA has recently commissioned feasibility investigations for the fishway on the National Channel. When the fishway has been completed at Cohuna Weir and if a fishway were constructed at Koondrook Weir, Gunbower Creek would then provide an alternative migration route around Torrumbarry Weir together with access to floodplain habitat in Gunbower Forest via the forest regulator fishways.

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Appendix 1: Threatened flora and fauna

The presence of species has been ascertained through:

EPBC Act, Protected Matters Search Tool website and includes species or species' habitat which may, are likely to or known to occur in the area
http://www.environment.gov.au/epbc/pmst/index.html ; and

Department of Sustainability and Environment, Biodiversity Interactive Map website
http://mapshare2.dse.vic.gov.au/MapShare2EXT/imf.jsp?site=bim

Threatened flora

Common Name	Scientific name	Flora and Fauna Guarantee Act 1988 (Vic)	DSE (2005) Advisory List of Rare or Threatened Plants in Victoria	EPBC Act 1999 (Cwlth)
Annual buttons	*Leptorhynchos orientalis*	L	E	
Blue burr-daisy	*Calotis cuneifolia*		R	
Bluish raspwort	*Haloragis glauca f. glauca*		PK	
Buloke	*Allocasuarina luehmannii*	L		
Buloke mistletoe	*Amyema linophylla* subsp. *orientale*		V	
Bundled peppercress	*Lepidium fasciculatum*		PK	
Chariot wheels	*Maireana cheelii*		V	E
Dark roly-poly	*Sclerolaena muricata* var. *semiglabra*		PK	
Dwarf Swainson-pea	*Swainsona phacoides*	L	E	
Frosted goosefoot	*Chenopodium desertorum* subsp. *desertorum*		R	
Fuzzy New Holland daisy	*Vittadinia cuneata var. hirsuta*		R	
Leafless bluebush	*Maireana aphylla*		PK	
Long Eryngium	*Eryngium paludosum*		V	
Native peppercress	*Lepidium pseudohyssopifolium*		PK	
Pale spike-sedge	*Eleocharis pallens*		PK	
Plains rice-flower, spiny rice-flower	*Pimelea spinescens subsp. spinescens*	L	V	CE
Red Darling-pea	*Swainsona plagiotropis*	L	V	V
River swamp wallaby-grass	*Amphibromus fluitans*			V
Riverina bitter-cress	*Cardamine moirensis*		R	

Common Name	Scientific name	Flora and Fauna Guarantee Act 1988 (Vic)	DSE (2005) Advisory List of Rare or Threatened Plants in Victoria	EPBC Act 1999 (Cwlth)
Slender Darling-pea	*Swainsona murrayana*	L	E	V
Smooth Minuria	*Minuria integerrima*		R	
Speargrass species	*Austrostipa wakoolica*			E
Squat Picris	*Picris squarrosa*		R	
Stiff groundsel	*Senecio behrianus*	L	E	E
Three-wing bluebush	*Maireana triptera*		R	
Twiggy Sida	*Sida intricata*		V	
Wavy marshwort	*Nymphoides crenata*	L	V	
Western water-starwort	*Callitriche cyclocarpa*	L	V	V
Winged pepper-cress	*Lepidium monoplocoides*	L	E	E

Legend

CE Critically endangered
PK Poorly known
E Endangered
L Listed
R Rare
V Vulnerable

Threatened fauna:

Common Name	Scientific Name	Flora and Fauna Guarantee Act 1988 (Vic)	DSE Threatened Species Advisory Lists	EPBC Act 1999 (Cwlth)
Birds				
Australasian bittern	*Botaurus poiciloptilus*	L	E	
Australasian shoveler	*Anas rhynchotis*		V	
Australian bustard	*Ardeotis australis*	L	CE	
Australian painted snipe	*Rostratula benghalensis australis* (*Rostratula australis*)	L	CR	V, M
Australian pratincole	*Stiltia isabella*		NT	
Azure kingfisher	*Alcedo azurea*		NT	
Baillon's crake	*Porzana pusilla palustris*	L	V	
Barking owl	*Ninox connivens connivens*	L	E	
Black falcon	*Falco subniger*		V	

Common Name	Scientific Name	Flora and Fauna Guarantee Act 1988 (Vic)	DSE Threatened Species Advisory Lists	EPBC Act 1999 (Cwlth)
Black-chinned honeyeater	*Melithreptus gularis gularis*		NT	
Black-eared cuckoo	*Chrysococcyx osculans*		NT	
Blue-billed duck	*Oxyura australis*	L	E	
Brolga	*Grus rubicunda*	L	V	
Brown quail	*Coturnix ypsilophora australis*		NT	
Brown treecreeper (south-eastern ssp.)	*Climacteris picumnus victoriae*		NT	
Bush stone-curlew	*Burhinus grallarius*	L	E	
Cattle egret	*Ardea ibis*			M
Common greenshank	*Tringa nebularia*			M
Diamond dove	*Geopelia cuneata*	L	NT	
Diamond firetail	*Stagonopleura guttata*	L	V	
Eastern great egret	*Ardea modesta (alba)*	L	V	M
Fork-tailed swift	*Apus pacificus*			M
Glossy ibis	*Plegadis falcinellus*		NT	M
Grey falcon	*Falco hypoleucos*	L	E	
Grey goshawk	*Accipiter novaehollandiae novaehollandiae*	L	V	
Grey plover	*Pluvialis squatarola*		NT	M
Grey-crowned babbler	*Pomatostomus temporalis temporalis*	L	E	
Ground cuckoo-shrike	*Coracina maxima*	L	V	
Gull-billed tern	*Gelochelidon (Sterna) nilotica macrotarsa*	L	E	
Hardhead	*Aythya australis*		V	
Hooded robin	*Melanodryas cucullata cucullata*	L	NT	
Intermediate egret	*Ardea intermedia*	L	CE	
Latham's snipe	*Gallinago hardwickii*		NT	M
Little bittern	*Ixobrychus minutus dubius*	L	E	
Little button-quail	*Turnix velox*		NT	

Common Name	Scientific Name	Flora and Fauna Guarantee Act 1988 (Vic)	DSE Threatened Species Advisory Lists	EPBC Act 1999 (Cwlth)
Little egret	*Egretta garzetta nigripes*	L	E	
Malleefowl	*Leipoa ocellata*	L	E	V, M
Musk duck	*Biziura lobata*		V	
Nankeen night heron	*Nycticorax caledonicus hillii*		NT	
Pied cormorant	*Phalacrocorax varius*		NT	
Plains-wanderer	*Pedionomus torquatus*	L	CE	V
Rainbow bee-eater	*Merops ornatus*			M
Red-backed kingfisher	*Todiramphus pyrropygia*		NT	
Red-chested button-quail	*Turnix pyrrhothorax*	L	V	
Regent honeyeater	*Anthochaera Phrygia* *(Xanthomyza phrygia)*	L	CE	E, M
Royal spoonbill	*Platalea regia*		V	
Spotted harrier	*Circus assimilis*		NT	
Square-tailed kite	*Lophoictinia isura*	L	V	
Superb parrot	*Polytelis swainsonii*	L	E	V
Swift parrot	*Lathamus discolor*	L	E	E
Whiskered tern	*Chlidonias hybridus javanicus*		NT	
White-bellied sea-eagle	*Haliaeetus leucogaster*	L	V	M
White-throated needletail	*Hirundapus caudacutus*			M
Mammals				
Greater Long-eared Bat	*Nyctophilus timoriensis* - south-eastern form *(Nyctophilus corbeni)*	L	V	V
Rufous bettong	*Aepyprymnus rufescens*	L	RX	
Squirrel glider	*Petaurus norfolcensis*	L	E	
Fish				
Crimson-spotted rainbowfish	*Melanotaenia fluviatilis*	L	DD	
Freshwater catfish	*Tandanus tandanus*	L	E	
Golden perch	*Macquaria ambigua*		V	

Common Name	Scientific Name	Flora and Fauna Guarantee Act 1988 (Vic)	DSE Threatened Species Advisory Lists	EPBC Act 1999 (Cwlth)
Macquarie perch	*Macquaria australasica*	E	L	E
Murray cod	*Maccullochella peelii peelii*	L	E	V
Murray hardyhead	*Craterocephalus fluviatilis*	L	CE	V
Silver perch	*Bidyanus bidyanus*	L	CE	
Trout cod	*Maccullochella macquariensis*	L	CE	E
Unspecked hardyhead	*Craterocephalus stercusmuscarum fulvus*	L	DD	
Frogs				
Brown toadlet	*Pseudophryne bibronii*	L	E	
Giant bullfrog	*Limnodynastes interioris*	L	CE	
Growling grass frog	*Litoria raniformis*	L	E	V
Reptiles				
Bearded dragon	*Pogona barbata*		DD	
Broad-shelled turtle	*Macrochelodina expansa*	L	E	
Carpet python	*Morelia spilota metcalfei*	L	E	
Lace goanna	*Varanus varius*		V	
Striped legless lizard	*Delma impar*	L	E	V
Woodland blind snake	*Ramphotyphlops proximus*		NT	

Legend

CE Critically endangered
DD Data deficient
E Endangered
L Listed
M Fauna protected under migratory bird agreements
NT Near threatened
RX Regionally extinct
V Vulnerable

Appendix 2: Monthly streamflows at key locations

All information presented in this appendix is sourced from MSM-Bigmod run #22061.

Average daily flows (ML/d) for the Murray River downstream of Hume Dam (1895–2009)

Month	Very dry year (minimum on record)	Dry year (30th percentile daily flow)	Median year (50th percentile daily flow)	Wet year (70th percentile daily flow)
Jul	629	629	629	629
Aug	629	629	629	9,713
Sep	650	650	7,234	16,595
Oct	629	11,115	16,375	21,273
Nov	650	13,865	17,720	21,677
Dec	629	15,467	18,222	20,536
Jan	3,468	17,043	18,937	20,638
Feb	696	14,717	16,877	18,429
Mar	533	14,895	17,811	20,221
Apr	569	7,725	11,103	13,734
May	629	629	1,644	3,790
Jun	650	650	650	686

Note: This data is sourced from MSM-Bigmod for flow immediately downstream of Hume Dam and does not include Kiewa River. The results shown for minimum flows may be an artefact of the modelling. The minimum daily flow in January in 1956 was 3,468 ML/d when allocations were high (full allocation to NSW high and general-security entitlements and Victorian high and low-reliability water shares). This occurs because wet catchment conditions (including high tributary inflows), combined with low demand, reduce the need for releases from storage. The minimum daily flow in January 2007 when allocations were at record lows was 13,907 ML/d. In December and February, releases of only 600–700 ML/d were modelled as occurring in isolated years as a result of short-term reductions in demands coupled with moderate or high tributary inflows.

Similar observations can be made about the minimum modelled flows at other sites in this Appendix.

Average daily flows (ML/d) for the Kiewa River at Bandiana (1895–2009)

Month	Very dry year (minimum on record)	Dry year (30th percentile daily flow)	Median year (50th percentile daily flow)	Wet year (70th percentile daily flow)
Jul	381	1,319	1,879	2,881
Aug	324	1,657	2,481	3,369
Sep	367	2,523	3,081	4,344
Oct	115	2,507	3,392	4,316
Nov	48	1,196	1,775	2,708
Dec	0	632	842	1,268
Jan	0	631	453	690
Feb	0	217	345	479
Mar	0	193	310	482
Apr	18	282	426	630
May	0	552	721	1,128
Jun	179	852	1,336	2,084

Average daily flows (ML/d) for the Murray River at Doctors Point (1895–2009)

Month	Very dry year (minimum on record)	Dry year (30th percentile daily flow)	Median year (50th percentile daily flow)	Wet year (70th percentile daily flow)
Jul	1,172	2,114	2,963	4,247
Aug	1,241	3,268	5,066	11,053
Sep	1,661	5,295	9,680	18,828
Oct	2,633	13,981	18,819	24,980
Nov	2,063	15,663	19,453	23,705
Dec	1,877	16,517	18,980	21,234
Jan	5,263	17,641	19,350	21,018
Feb	2,633	15,116	17,091	18,648
Mar	648	15,223	18,149	20,387
Apr	667	8,270	11,565	14,112
May	1,142	1,787	2,962	4,431
Jun	1,168	1,733	2,309	3,576

Average daily flows (ML/d) for the Ovens River at Peechelba East (1895–2009)

Month	Very dry year (minimum on record)	Dry year (30th percentile daily flow)	Median year (50th percentile daily flow)	Wet year (70th percentile daily flow)
Jul	137	3,278	5,543	9,738
Aug	222	5,105	8,160	12,803
Sep	162	5,112	7,889	11,224
Oct	10	3,363	5,755	8,842
Nov	9	1,918	3,094	4,794
Dec	0	947	1,487	2,424
Jan	0	214	563	1,172
Feb	0	140	222	662
Mar	0	136	171	551
Apr	0	144	254	830
May	0	573	1,218	2,191
Jun	2	1,357	2,769	5,080

Average daily streamflows (ML/d) for the Murray River downstream of Yarrawonga Weir (1895–2009)

Month	Very dry year (minimum on record)	Dry year (30th percentile daily flow)	Median year (50th percentile daily flow)	Wet year (70th percentile daily flow)
Jul	1,806	5,505	8,538	14,718
Aug	1,953	7,902	12,706	20,080
Sep	1,906	8,379	13,202	25,360
Oct	3,018	10,308	13,919	20,499
Nov	1,800	11,454	15,210	17,785
Dec	1,806	10,600	11,236	12,903
Jan	3,044	8,891	10,339	10,600
Feb	1,786	8,126	8,921	9,910
Mar	3,209	8,920	9,660	10,506
Apr	1,800	7,033	8,619	9,926
May	1,806	2,991	4,204	5,866
Jun	1,800	3,236	4,973	8,463

Average daily streamflows (ML/d) for the Murray River at Barmah (1895–2009)

Month	Very dry year (minimum on record)	Dry year (30th percentile daily flow)	Median year (50th percentile daily flow)	Wet year (70th percentile daily flow)
Jul	1,541	4,699	6,841	10,267
Aug	1,876	6,550	9,378	13,552
Sep	2,183	7,690	10,965	16,416
Oct	2,181	8,070	10,438	16,653
Nov	3,051	9,148	10,885	13,242
Dec	3,364	8,198	9,025	10,143
Jan	3,767	7,221	7,898	8,251
Feb	4,119	6,352	7,001	7,804
Mar	3,331	6,811	7,370	7,962
Apr	2,290	6,496	7,554	8,371
May	1,747	3,440	4,609	6,226
Jun	1,548	2,796	3,916	6,582

Average daily streamflows (ML/d) for Broken Creek at Rices Weir (1895–2009)

Month	Very dry year (minimum on record)	Dry year (30th percentile daily flow)	Median year (50th percentile daily flow)	Wet year (70th percentile daily flow)
Jul	0	75	176	358
Aug	0	248	340	450
Sep	0	646	606	836
Oct	0	159	428	965
Nov	0	155	417	851
Dec	0	246	311	416
Jan	0	220	274	356
Feb	0	286	343	404
Mar	0	242	302	406
Apr	0	396	469	582
May	3	426	484	585
Jun	0	58	133	233

Average daily streamflows (ML/d) for the Goulburn River at McCoys Bridge (1895–2009)

Month	Very dry year (minimum on record)	Dry year (30th percentile daily flow)	Median year (50th percentile daily flow)	Wet year (70th percentile daily flow)
Jul	344	1,094	2,874	7,533
Aug	195	2,448	5,838	11,457
Sep	135	2,307	4,570	9,394
Oct	332	1,256	2,327	4,374
Nov	428	985	1,511	2,609
Dec	830	1,500	1,674	2,337
Jan	374	1,514	1,606	1,747
Feb	204	1,547	1,624	1,741
Mar	330	408	452	654
Apr	256	416	528	734
May	350	350	464	796
Jun	350	544	859	2,348

Average daily streamflows (ML/d) for the Campaspe River at Rochester (1895–2009)

Month	Very dry year (minimum on record)	Dry year (30th percentile daily flow)	Median year (50th percentile daily flow)	Wet year (70th percentile daily flow)
Jul	0	67	122	325
Aug	0	88	211	640
Sep	0	70	196	740
Oct	0	69	74	174
Nov	0	38	70	70
Dec	0	32	43	70
Jan	0	27	35	51
Feb	0	20	35	66
Mar	0	16	35	61
Apr	0	18	35	59
May	0	35	35	70
Jun	0	35	70	145

Average daily streamflows (ML/d) for the Murray River downstream of Torrumbarry Weir (1895–2009)

Month	Very dry year (minimum on record)	Dry year (30th percentile daily flow)	Median year (50th percentile daily flow)	Wet year (70th percentile daily flow)
Jul	1,752	6,073	9,271	18,278
Aug	245	6,924	13,124	24,475
Sep	2,118	7,938	15,286	26,881
Oct	2,113	6,375	10,322	19,228
Nov	1,659	6,601	8,873	12,869
Dec	1,913	6,458	7,919	9,562
Jan	2,548	5,173	5,777	6,516
Feb	2,573	4,860	5,677	6,441
Mar	2,118	3,700	4,311	4,781
Apr	1,880	4,398	5,413	6,572
May	1,537	3,849	4,898	6,851
Jun	1,902	3,642	5,236	9,075

Average daily streamflows (ML/d) for the Loddon River downstream of Kerang Weir (1895–2009)

Month	Very dry year (minimum on record)	Dry year (30th percentile daily flow)	Median year (50th percentile daily flow)	Wet year (70th percentile daily flow)
Jul	0	154	232	468
Aug	0	236	484	870
Sep	0	420	628	987
Oct	0	255	464	814
Nov	0	224	332	476
Dec	0	23	95	135
Jan	0	143	172	226
Feb	22	154	186	234
Mar	0	114	130	146
Apr	0	150	210	325
May	24	502	529	751
Jun	0	168	198	316

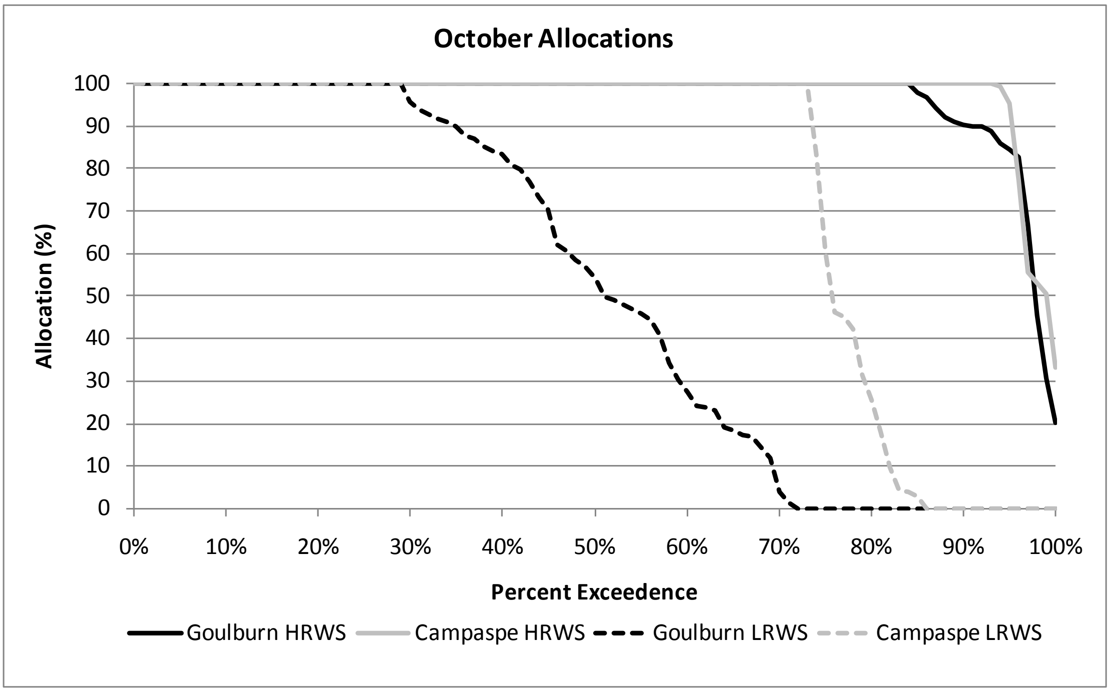
Average daily streamflows (ML/d) for the Murray River at Barham (1895–2009)

Month	Very dry year (minimum on record)	Dry year (30th percentile daily flow)	Median year (50th percentile daily flow)	Wet year (70th percentile daily flow)
Jul	1,842	5,929	8,970	16,066
Aug	426	6,842	12,862	17,591
Sep	1,939	7,824	14,985	17,905
Oct	2,103	6,207	10,220	16,264
Nov	2,262	6,384	8,709	12,705
Dec	2,589	6,196	7,764	9,396
Jan	2,284	4,894	5,495	6,270
Feb	2,473	4,607	5,403	6,118
Mar	2,260	3,503	4,083	4,589
Apr	2,007	4,210	5,158	6,257
May	1,678	3,894	4,955	6,823
Jun	1,943	3,588	4,957	8,613

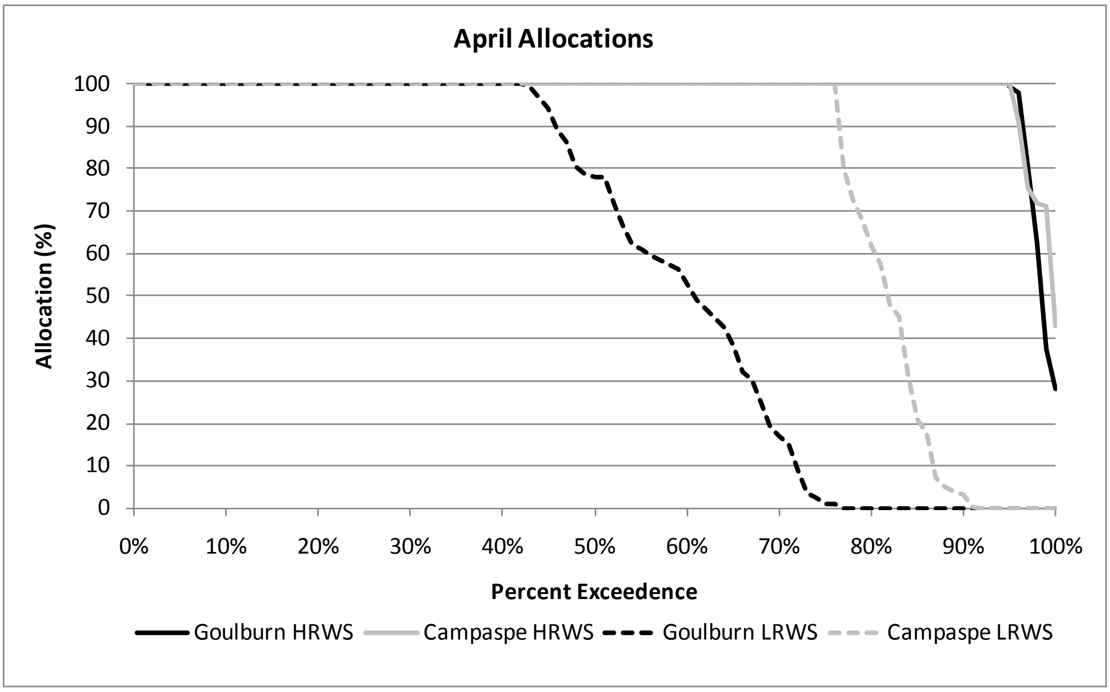
Average daily streamflows (ML/d) for the Murray River at Pental Island (1895–2009)

Month	Very dry year (minimum on record)	Dry year (30th percentile daily flow)	Median year (50th percentile daily flow)	Wet year (70th percentile daily flow)
Jul	1,735	5,975	9,368	13,185
Aug	1,148	7,143	11,512	14,779
Sep	1,862	8,680	12,369	15,235
Oct	1,674	6,606	10,598	14,036
Nov	1,961	6,668	9,167	11,496
Dec	2,190	5,812	7,448	9,255
Jan	2,196	4,688	5,322	6,089
Feb	2,236	4,294	5,066	5,810
Mar	1,891	3,207	3,671	4,250
Apr	2,006	4,211	5,154	6,433
May	1,982	4,711	5,773	7,680
Jun	1,793	3,718	4,970	8,813

Appendix 3: Seasonal allocations



October seasonal allocations for the Goulburn and Campaspe systems.



April seasonal allocations for the Goulburn and Campaspe systems.

Appendix 4: Operational monitoring report template

Commonwealth Environmental Watering Program *Operational Monitoring Report* *Please provide the completed form to <insert name and email address>, within two weeks of completion of water delivery or, if water delivery lasts longer than 2 months, also supply intermediate reports at monthly intervals.*			
Final Operational Report	Intermediate Operational Report	Reporting Period: From	To
Site name		**Date**	
Location	GPS Coordinates or Map Reference for site (if not previously provided)		
Contact Name	*Contact details for first point of contact for this watering event*		
Event details	*Watering Objective(s)*		
	Total volume of water allocated for the watering event *Commonwealth Environmental Water:* *Other (please specify):*		
	Total volume of water delivered in watering event *Commonwealth Environmental Water:* *Other (please specify):*	*Delivery measurement* *Delivery mechanism:* *Method of measurement:* *Measurement location:*	
	Delivery start date (and end date if final report) of watering event ?		
	Please provide details of any complementary works.		
	If a deviation has occurred between agreed and actual delivery volumes or delivery arrangements, please provide detail.		
	Maximum area inundated (ha) (if final report)?		
	Estimated duration of inundation (if known)[1]?		
Risk management	*Please describe the measure(s) that were undertaken to mitigate identified risks for the watering event (eg. water quality, alien species); please attach any relevant monitoring data. Have any risks eventuated? Did any risk issue(s) arise that had not been identified prior to delivery? Have any additional management steps been taken?*		
Other Issues	*Have any other significant issues been encountered during delivery?*		
Initial Observations	*Please describe and provide details of any species of conservation significance (state or Commonwealth listed threatened species, or listed migratory species) observed at the site during the watering event.*		
	Please describe and provide details of any breeding of frogs, birds or other prominent species observed at the site during the watering event.		
	Please describe and provide details of any observable responses in vegetation, such as improved vigour or significant new growth, following the watering event.		
	Any other observations?		
Photographs	*Please attach photographs of the site prior, during and after delivery[2]*		

1 Please provide the actual duration (or a more accurate estimation) at a later date (e.g. when intervention monitoring reports are supplied).

2 For internal use. Permission will be sought before any public use.

Appendix 5: Risk assessment matrices

Risk likelihood rating

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

Risk consequence rating

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

Risk analysis matrix

LIKELIHOOD	CONSEQUENCE				
	Insignificant	Minor	Moderate	Major	Critical
Almost certain	Low	Medium	High	Severe	Severe
Likely	Low	Medium	Medium	High	Severe
Possible	Low	Low	Medium	High	Severe
Unlikely	Low	Low	Low	Medium	High
Rare	Low	Low	Low	Medium	High

WAT086.0211