Australian Government

Commonwealth Environmental Water

ENVIRONMENTAL WATER DELIVERY:

Yarrawonga to Tocumwal and Barmah-Millewa

AUGUST 2011 V1.0

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Barmah Forest along the Choke
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Barmah Island and Broken Creek
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The Murray at Fisherman's Bend
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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 will be seeking information on:

- community views on environmental assets and the health of these assets
- views on the prioritisation of environmental water use
- potential partnership arrangements for the management of environmental water
- 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 the Barmah-Millewa forest and Murray River floodplain between Yarrawonga and Tocumwal.

The Barmah-Millewa system includes extensive areas of internationally significant wetlands and provides habitat for a wide range of flora and fauna species. Potential water use options for Barmah-Millewa include the provision of spring flows through the Barmah-Millewa regulators to provide low level inundation of the forest. This is expected to support small scale recruitment of waterbirds, breeding opportunities for turtles and improve the condition of giant rush, moira grass and river red gum forest communities.

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 Australian Government Department of Sustainability, Environment, Water, Population and Communities. Previously prepared work has been drawn upon and discussions have occurred with organisations such as the Victorian Department of Sustainability and Environment, NSW Office of Environment and Heritage, NSW Office of Water, NSW State Water Corporation, Goulburn Broken Catchment Management Authority, Murray 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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Acronyms

ACRONYM	MEANING
BE	Bulk entitlement
CEWH	Commonwealth Environmental Water Holder
COAG	Council of Australian Governments
DO	Dissolved oxygen
DPI	NSW Department of Primary Industries
DSE	Victorian Department of Sustainability and Environment
EPBC Act	*Environment Protection and Biodiversity Conservation Act 1999 (Commonwealth)*
EVC	Ecological vegetation classes
EWA	Environmental Water Allowance
EWAG	Environmental Watering Advisory Group
EWMP	Environmental Water Management Plan
GMW	Goulburn-Murray Water
ICC	Barmah-Millewa Integrated Coordinating Committee
IRG	Indigenous Reference Group
IVTs	Inter-valley transfers
MCMA	Murray Catchment Management Authority
MDBA	Murray-Darling Basin Authority
MIL	Murray Irrigation Limited
NC CMA	North Central Catchment Management Authority
NPWS	NSW National Parks and Wildlife Service
OEH	NSW Office of Environment and Heritage
NRSWS	The Northern Region Sustainable Water Strategy
SEWPaC	Commonwealth Department of Sustainability, Environment, Water, Population and Communities
TAC	Technical Advisory Committee
TLM	The Living Murray program
YBM	Yarrawonga to Tocumwal Reach and Barmah-Millewa

PART 1:
Management Aims

1. Overview

1.1 Scope and purpose of the plan

Information in this document is intended to help establish an operational planning framework that provides scalable strategies for environmental water use based on the demand profiles for 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. It specifically targets large scale water use options for large volumes of environmental water.

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

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

As part of this larger project, assets and potential watering options are identified for regions across the Basin. This work has been undertaken in three steps:

1. 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.
2. Water use strategies will be developed for each asset that meet watering objectives under a range of water availability scenarios. Efforts are also made to optimise the use of environmental water to maximise environmental outcomes at multiple assets, where possible. In the first instance, water use strategies will provide an "event ready" basis for the allocation of Commonwealth environmental water in the 2011 autumn and spring seasons. These strategies will be integrated into a five-year water delivery program.

3. Processes and mechanisms required to operationalise environmental water use 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 or methodologies that 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 outlines proposed objectives for environmental water delivery in the floodplain assets of:

- the Murray River floodplain between Yarrawonga and the Barmah-Millewa forest
- the Barmah-Millewa forest (Figure 1).

It is anticipated that future water delivery planning will include the Tuppal-Bullatale distributary system that diverts water from the Murray River near Tocumwal to the Edward River near Deniliquin. The ecological objectives and delivery options for this system require further assessment before inclusion in these planning documents.

NOTE: an operating strategy is under development for the Barmah-Millewa site. This document does not prescribe particular watering events; rather it describes an effective platform for operational decision making based on knowledge of the system and an understanding of site objectives.

The Barmah-Millewa forest (and Murray River floodplain upstream) are within a larger water planning area of the Central Murray Floodplain (Yarrawonga to the Wakool junction). Actions and activities identified within this document must be considered in conjunction with adjoining water delivery for the Edward-Wakool, Koondrook-Perricoota and Gunbower Forests.

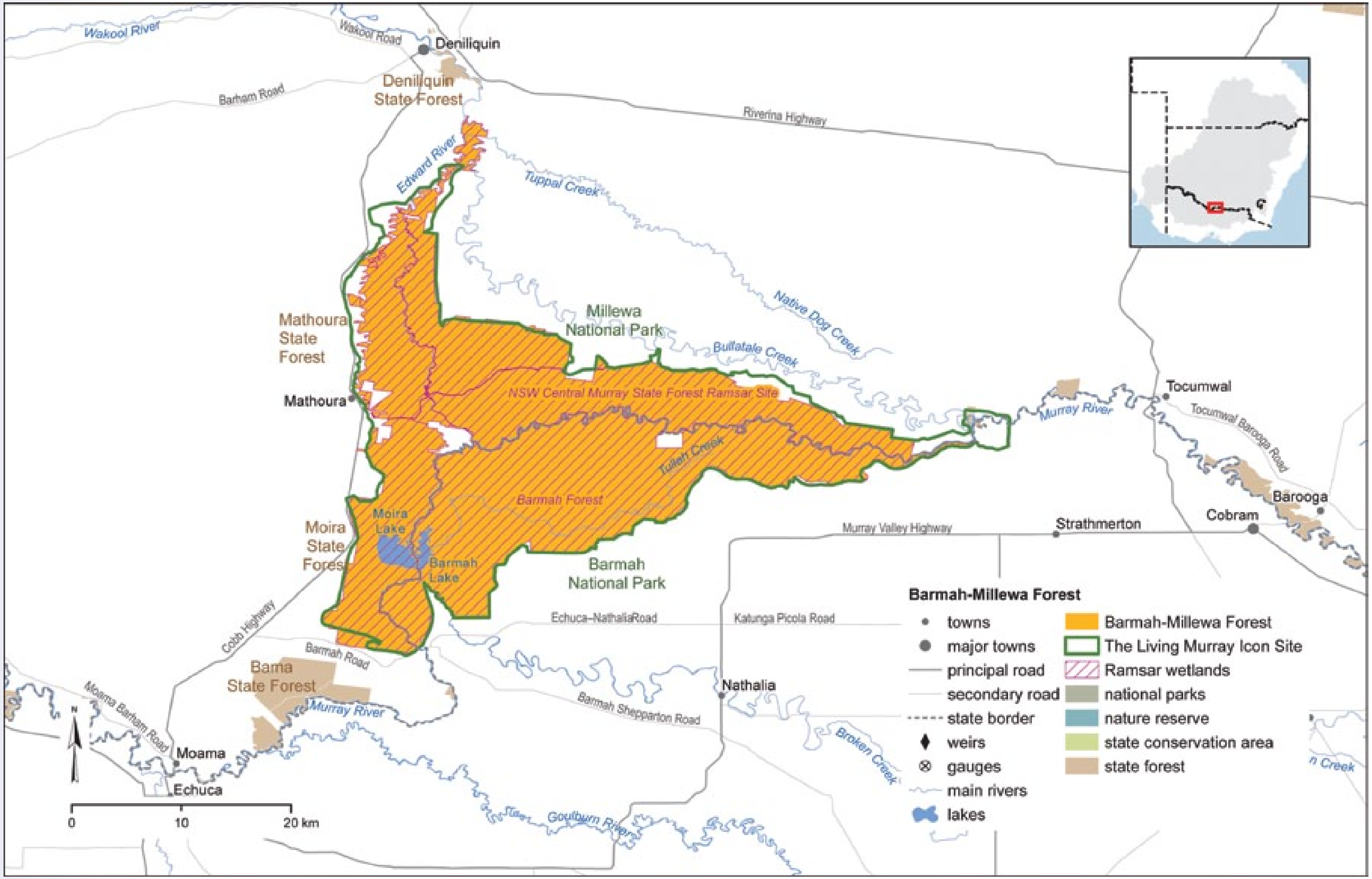

Figure 1: Location of Barmah-Millewa forest (MDBA 2010a).

1.2 Catchment and river system overview

The Yarrawonga to Tocumwal Reach and Barmah-Millewa (YBM) system is part of the Murray River catchment.

The upper Murray River catchment straddles New South Wales and Victoria, extending along the length of the Murray River from its headwaters in the Great Dividing Range to its convergence with the Edward River downstream of Swan Hill. 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, as well as the Mitta Mitta River, which connects Dartmouth Dam to Hume Dam. The upper Murray River from Lake Hume to the Wakool River junction is a braided stream with a complex network of major and minor anabranches, including the Edward-Wakool river system which offtakes between Yarrawonga and Barmah and converges with the main stem of the Murray River at the Wakool River junction downstream of Swan Hill. Downstream of Albury, 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 Kiewa, Ovens, Goulburn, Campaspe and Loddon Rivers and Broken Creek, which enter from the south (CSIRO 2008).

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

The major flow regulating structures in the upper Murray upstream of YBM are Dartmouth Dam (3,856 GL capacity), Hume Dam (3,005 GL capacity) and Yarrawonga Weir (118 GL capacity). Diversions from the Snowy River into the Murray catchment via the Snowy Mountains Hydroelectric Scheme add around 640 GL/yr on average to flows in the Upper Murray (CSIRO 2008).

1.3 Overview of river operating environment

The Barmah-Millewa forest is located on the Murray River floodplain downstream of Tocumwal and upstream of Echuca. Flows in the Murray River under regulated flow conditions are sourced from Hume Dam, which releases water to Yarrawonga Weir and areas downstream. In very dry years, when storage in Lake Victoria and Menindee Lakes is low, additional releases are made specifically for South Australian requirements.

Hume Reservoir generally follows an annual cycle of filling and drawdown. The storage takes in water during winter and spring and on average has spilled about one year in two. In the recent drought, the reservoir only spilled in October 2000, but would have also spilled in 2004 if not for releases being made from the Barmah-Millewa allowance for environmental flows in that year. Releases are usually made from November to May. By the end of autumn the storage is usually drawn down to between 10 per cent and 50 per cent capacity (MDBA 2010c).

Hume and Dartmouth are operated in a coordinated (or "harmony") operation, with releases being made from Dartmouth to share the available "airspace" between the two storages. Airspace is the difference between the volume of water actually in the storage and the volume which would be held in the storage if it was full. Harmony operation maximises the volume of water available for downstream uses, and also maximises the capacity to mitigate floods downstream of the dams (MDBA 2010c).

Hume Reservoir has modified the downstream natural flow pattern of the Murray by reducing winter and early spring flows and increasing summer flows (MDBA 2010c). Releases from the Snowy Mountains Hydroelectric Scheme also increase summer flows, although their seasonal effect downstream of Hume Dam is mitigated by the upstream storages.

Flows are diverted at Yarrawonga Weir to supply several irrigation districts in New South Wales (Berriquin, Deniboota, Bullatale Creek, Moira, West Corurgan, Denimein and Wakool) and the Murray Valley Irrigation Area in Victoria. The Murray continues to carry regulated flows destined for irrigation districts further downstream, some of which is passed via the Edward River and Gulpa Creek.

The Barmah Choke in the Barmah-Millewa forest forms a natural constraint on the volume of water that can be delivered along the Murray River under regulated flow conditions. Murray-Darling Basin Authority (MDBA) river operators bypass some flow around the Choke using spare capacity in irrigation channels in both New South Wales and Victoria when necessary and feasible (depending on irrigation channel spare capacity). The river is operated during the irrigation season to keep flows within the river channel through the Choke to avoid delivery forfeit and adverse environmental impacts associated with unseasonal overbank flooding into the Barmah-Millewa forest. Flow regulators exist on both sides of the river which can manipulate the volume of water entering or leaving the forest via flood runners. The Ovens River and the Kiewa River enters below Hume and provides significant unregulated inflows to the Murray River above the Barmah-Millewa forest.

At flow rates of up to 10,600 ML/d downstream of Yarrawonga, flows remain in channel through the Barmah-Millewa forest with the forest flow regulators closed. This represents the normal maximum channel capacity for regulated river operations. At this flow rate, 8,500 ML/d passes through the Choke and 2,100 ML/d is diverted via the Edward River and Gulpa Creek. At flows as low as 3,000 ML/d, water can enter the forest when the forest regulators are open. At flows above around 10,600 ML/d, effluent creeks into the Barmah-Millewa forest start to flow over the forest regulators. During floods, operation of the river system can change significantly. Pre-releases are made from Hume Dam when the reservoir is assured of spilling based on minimum forecast inflows if additional airspace is required in Hume Dam to mitigate flood peaks. At flows above around 20,000 ML/d, some of the effluent creeks start to flow between Yarrawonga and Picnic Point into the Edward River, while some of the effluent creeks do not commence to flow until Murray River flows are above 100,000 ML/d, as outlined in greater detail in the environmental water delivery document for the Edward-Wakool system. In very high flow events, the volume of Murray River water passing through the Edward-Wakool system can be in the order of five times greater than that passing through the main stem of the Murray River immediately downstream of the forest.

2. Ecological values, processes and objectives

2.1 Ecological values

There are a number of significant ecological values within the streams and wetlands of the YBM system. The system supports over 100 significant flora and fauna species (see Appendix A) and contains two internationally significant wetlands: Barmah Forest Ramsar site and Millewa Forest, which is part of the Central Murray State Forests Ramsar Site. In addition, these two internationally recognised wetlands have recently been declared national parks under respective state legislation.

2.1.1 The Murray River from Yarrawonga to Tocumwal

The Murray River floodplain between Yarrawonga and Tocumwal is confined to a corridor approximately 1.5 kilometres wide. The floodplain comprises predominantly river red gum (*Eucalyptus camaldulensis*) forest and features wetlands, anabranches and floodrunners. This reach provides habitat for the nationally endangered trout cod (*Maccullochella macquariensis*) where it favours the wide (60 to 100 metre) channel, fast-flowing and deep (>3 metres) conditions and a sand, silt and clay substrate with abundant snags and woody debris (Koehn et al. 2008). This reach also supports populations of silver perch (*Bidyanus bidyanus*) and Murray hardyhead (*Craterocephalus fluviatilis*); both species are listed under the *Environmental Protection and Biodiversity Conservation Act 1999 (Commonwealth)*, with a national recovery plan developed for the Murray hardyhead (Backhouse et al. 2008). The nationally vulnerable Murray cod (*Maccullochella peelii*) are abundant (REG C 2003).

2.1.2 Barmah-Millewa forests

The Barmah-Millewa site, composed of the Barmah forest in Victoria and the Millewa group of forests in New South Wales, is the largest river red gum forest in Australia. It covers approximately 66,000 hectares of floodplain between the townships of Tocumwal, Deniliquin and Echuca and contains extensive floodplain vegetation communities (Table 1), along with a diverse range of wetland environments (Gippel 2005).

Table 1: Area of key vegetation communities within Barmah-Millewa forests (MDBA 2010a).

Vegetation Types	Barmah (ha)	Millewa (ha)	Total Area (ha)
Giant rush	531	2,667^	3,198
Moira grass	1,535	774^	2,309
River red gum forest (with a flood dependent understorey)	16,617	26,181	42,798
River red gum woodland (with flood tolerant understorey)	9,711	4,002	13,713
River red gum / black box woodland	1,063	2,919	3,982
Total	29,457	36,543	66,000

^ Areas shown are derived from the area of wetland as the precise areas of giant rush and moira grass were not directly identified in the source document.

Watercourses

There are a number of streams that divert water from the main stem of the Murray River into the Barmah-Millewa floodplain. These streams provide important seasonal habitat for a range of aquatic fauna, particularly fish. Through-flow at critical times maintains aquatic habitat and provides fish passage between sites within the forest and wetlands and to the Murray River. Freshes in spring trigger spawning in many species and, by providing access to adjacent flooded wetland habitat, provide nursery habitat for juveniles.

Through-flow also maintains water quality. Blackwater events occur from time to time in Barmah-Millewa forest and have resulted in fish deaths. Similarly, river red gum trees lining the watercourses depend on creek water to maintain their health. At high sustained flows, trees lining the watercourses provide nesting habitat for waterbirds.

Wetlands

The Barmah-Millewa system has large wetlands and lakes, which feature a combination of open water, submerged aquatic macrophytes and are fringed by extensive beds of giant rush (*Juncus ingens*). Until the recent severe drought conditions, several wetlands had never dried before in recorded history and acted as important refuges for waterbirds and aquatic fauna, including a significant native fish community. The wetlands are important waterbird breeding sites and will support breeding of a range of species when flooded in late spring and summer. Important wetland sites include Douglas Swamp, Boals-Deadwoods, St Helena Swamp, Black Swamp, Walthours Swamp, Moira Lake, the Gulpa Creek Complex and Barmah Lake.

Moira grass plains

Moira grass (*Pseudoraphis spinescens*) plains are an important feature of Barmah-Millewa forest. These plains occupy floodplain elevations between the permanent wetlands and the higher river red gum forest. The moira grass plains are important botanically, but also provide foraging habitat for nesting waterbirds and productive habitat for fish and macro invertebrates. When flooded, these are highly significant as breeding and feeding habitat for colonial breeding water birds like egrets, herons, spoonbills and whiskered terns.

River red gum forest and woodland

River red gum forest and woodland occupies the floodplain at elevations inundated by flows of 15,000 to 35,000 ML/d. Inundation in winter and spring supports the growth of mature trees and a range of understorey species including warrego summer grass (*Paspalidium judiflorum*) and rush sedge (*Carex tereticaulis*), as well as the nationally vulnerable swamp wallaby grass (*Amphibromus fluitans*).

Mature river red gums along the Edward River (in Millewa forest) and in the east of the Barmah forest provide bioregionally significant nesting habitat for the nationally threatened superb parrot (*Polytelis swainsonii)*. Inundated forest is regionally significant as colonial nesting waterbird habitat with over 100,000 nesting birds recorded during large natural floods (Harrington and Hale 2011; Hale and Butcher in prep). The site is also significant for native fish recruitment at a bioregional scale. In addition, floodplain forest inundation is significant in terms of river productivity (Harrington and Hale 2011). The recession of flood water in spring and summer promotes the germination of river red gum seedlings and provides a productive understorey for a range of forest fauna, including herbivorous and insectivorous mammals, birds and reptiles.

2.2 Current condition

Open water bodies and giant rush plant communities occupy the lowest parts of the floodplain. Giant rush is favoured by summer and autumn flooding which has increased since the construction of the Hume Dam in 1934. River red gum trees have died as a result of prolonged inundation, and giant rush and open water habitat have increased at the expense of moira grass, which occupied 13.5 per cent of the floodplain in 1930 but only 5.5 per cent in 1980 (Chesterfield 1986; Gippel 2005). In-channel flows downstream of Yarrawonga are limited to 10,600 ML/d, with higher flows causing spill in the floodplain. To maximise the delivery of water to downstream consumptive water users, the river is operated as close as possible to the channel limit. However, this results in ongoing spills when rainfall contributes additional flow or downstream consumptive water users reject ordered water. Rain rejection events occur most frequently in the irrigation season in late spring, summer and autumn. Frequent floodplain inundation at levels between 10,400 and 15,000 ML/d in summer and autumn can damage the Barmah-Millewa forest.

At higher floodplain levels, the frequency and duration of floods has decreased. Flows of between 13,000 and 55,000 ML/d, which are required to support moira grass plains and river red gum woodland and forest, have been depleted by river regulation and water extraction (Gippel 2005). In addition, Barmah-Millewa forest has experienced drought conditions between 2000 and 2009. In the period between the medium-size flood in 2005, when approximately 57 per cent of the floodplain was inundated and winter 2010, most of the forest's wetlands and waterways dried completely– many for the first time in decades and some possibly for the first time in recorded history (MDBA in prep.). However, widespread inundation did occur in spring 2010 and extended through summer 2011. The affects of this on the forest ecology is yet to be determined.

Decreased frequency and duration of inundation of moira grass plains has also promoted the establishment of river red gum in the upper limit of the plant community's range. Dense stands of river red gum trees have established across approximately 75 per cent of the Porters and Algeboia moira grass plains in the Millewa forests.

As a result of water resource use and prolonged drought, the condition of the river red gum and flood dependent understorey have declined. An assessment of forest condition in 2009 indicated that the majority of the trees were in moderate or poor condition across the Barmah-Millewa forest (Cunningham et al. 2009). Those stands remaining in good condition were restricted to areas surrounding the river, creeklines and wetlands. Understorey condition has also declined, with terrestrial species beginning to displace wetland species (Stokes et al. 2010). It is not yet known what the effect of the 2010–11 flood has had on vegetation condition within the site.

No major waterbird breeding events have occurred between the 2005–06 and 2010–11 floods. Small-scale breeding occurred in 2009–10 at several sites in Millewa forest that received environmental water and included species such as royal spoonbills, Australian white ibis, little pied cormorants, various egrets and a single pair of brolgas (MDBA in prep.). Recent observations suggest that the 2010–11 flood has resulted in large scale waterbird breeding within the forests (Rick Webster, NPWS, pers comm).

Increased periods between flood events results in organic matter accumulation on the floodplain, and dissolved oxygen concentrations can fall below the tolerances of fish and other aquatic fauna upon rewetting (Howitt et al. 2005). These are termed "blackwater" events. There are recent examples from the Barmah-Millewa forests, most notably in the floods of 2010, which inundated large areas of floodplain that had been dry for decades. Water discharging from the forest was very low in dissolved oxygen (less than 1 mg/L) causing decreased oxygen concentrations in the Edward and Murray Rivers (MDBA unpublished).

2.3 Ecological objectives

Environmental objectives and targets for the Barmah-Millewa forest have been developed through The Living Murray program.

Broadly, the ecological objectives are to:

- Maintain the extent and health of key vegetation communities (giant rush, moira grass and river red gum forest and woodland)
- Maintain native fish populations by stimulating breeding and providing connectivity between floodplain, wetland and river habitats
- Support waterbird breeding by provision of feeding and nesting habitat
- Provide habitat for aquatic fauna such as frogs, yabbies and turtles
- Manage the inundation of organic debris to export organic matter to Murray River and reduce summer blackwater risks.

The objectives are presented for four water availability scenarios (Table 2):

- Extreme dry years
- Dry years
- Median years
- Wet years.

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

In Barmah-Millewa forest, the permanent and semi-permanent aquatic habitats are the highest priority when environmental water is scarce. These are watered at low river thresholds by diverting water from the Murray River in winter and spring to internal forest wetlands and watercourses where resident populations of aquatic fauna, particularly fish, are maintained and waterbird drought refuge habitat can be provided.

When more water is available, it can be used to provide a higher ambient flow in the Murray River, which allows higher parts of the floodplain to be watered as well. A high priority is inundation of the moira grass plains, which require sustained and frequent inundation in winter and spring.

When large volumes of water are available it is possible to meet the water requirements of wetlands and watercourses, while also providing moira grass and river red gum forest inundation.

Water availability scenarios are not entirely independent of ambient flow conditions. However, even if water is available it is important that environmental water is used efficiently and this will often be when the flow thresholds of the targeted assets is 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.

Table 2: Ecological objectives for targeted water use.

	Extreme Dry	Dry	Median	Wet
Ecological objectives	Avoid damage to key environmental assets	Ensure ecological capacity for recovery	Maintain ecological health and resilience	Improve and extend healthy and resilient aquatic ecosystems
Watercourses (4,000 to 15,000 ML/d) measured at Yarrawonga	Maintain flow in creeks and refuge pools in winter and spring to: • maintain fish populations • maintain water quality in watercourses and refuge pools • provide lateral transfer of water into adjacent groundwater aquifers to maintain health of large riparian river red gums.	Provide sustained flow and freshes in creeks and refuge pools in winter and spring to: • maintain fish populations • stimulate fish breeding • inundate riparian river red gums • inundate organic debris and reduce summer blackwater risks • provide lateral transfer of water into adjacent groundwater aquifers to maintain health of large riparian river red gums.	Provide sustained flow with multiple peaks in winter and spring to: • achieve multiple fish spawning events • inundate organic debris, reduce summer blackwater risks and export organic matter to Murray River (including the Gulpa Creek and Edward-Wakool systems) • support waterbird nesting in riparian trees (i.e. maintain nesting and foraging habitat for colonial nesting waterbird species such as the egrets, herons and cormorants).	Provide sustained flows with connections to inundated floodplain habitat to: • process and export organic matter and support fish breeding. • support waterbird nesting in riparian trees (i.e. maintain nesting and foraging habitat for colonial nesting waterbird species such as the egrets, herons and cormorants).
Giant rush wetland (4,000 to 15,000 ML/d) measured at Yarrawonga	Flood some giant rush wetlands such as Douglas Swamp, St Helena Swamp, Black Swamp, Walthours Swamp and Gulpa Creek Wetland Complex (Reed Beds, Coppingers and Duck Lagoon). The flooding of some sites solely depends on the management of the Gulpa Creek and Edward River Offtake regulators.	Inundate giant rush wetlands to: • maintain vegetation health • provide adequate water depth and flood frequency to restrict invasion of giant rush and river red gums into open areas of water • provide feeding habitat for waterfowl • provide breeding habitat for some waterfowl species • provide habitat diversity and dispersal opportunities for fish, turtles and yabbies.	Inundate giant rush wetlands to: • initiate and support breeding by a variety of waterbirds such as ibis, swans, spoonbills, bitterns • provide additional habitat for fish, frogs, yabbies and turtles • maintain a mosaic of open water and rush/reed beds.	Inundate giant rush wetlands to: • initiate and support breeding by a variety of waterbirds such as ibis, swans, spoonbills, bitterns • provide additional habitat for fish, frogs, yabbies and turtles • maintain a mosaic of open water and rush/reed beds.

	Extreme Dry	Dry	Median	Wet
Ecological objectives	Avoid damage to key environmental assets	Ensure ecological capacity for recovery	Maintain ecological health and resilience	Improve and extend healthy and resilient aquatic ecosystems
Moira grass plain (13,000 to 25,000 ML/d) measured at Yarrawonga	None.	Inundate moira grass plains to: • maintain moira grass growth • provide adequate water depth and flood frequency to restrict invasion of giant rush and river red gums into moira grass plains.	Inundate moira grass plains to: • maintain moira grass growth and vegetative reproduction • provide nesting and foraging habitat for waterbirds such as egrets, herons, grebes, terns. • provide adequate water depth and flood frequency to restrict invasion of giant rush and river red gums into moira grass plains. Allow fish to return to permanent habitat on the flood recession.	Inundate moira grass plains to: • maintain moira grass growth and flowering/seeding • provide nesting and foraging habitat for waterbirds such as egrets, herons, grebes, terns. • provide adequate water depth and flood frequency to restrict invasion of giant rush and river red gums into moira grass plains. Allow fish to return to permanent habitat on the flood recession.
River red gum forest (20,000 to 35,000 ML/d) measured at Yarrawonga	None.	None.	Inundate river red gum to: • maintain river red gum growth • 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 river red gum growth and reproduction • inundate terete culm sedge community • provide feeding locations for waterbirds • 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.

3. Watering objectives

3.1 Watering Objectives

Water regimes to achieve the ecological objectives described in section 2.3 may be determined on the basis of the ecology of key species, forest hydrology and observed responses to natural and managed floods (Figure 2, Table 3).

Options have been developed for the use of environmental water to bring the water regime of the Yarrawonga to Tocumwal Reach and Barmah-Millewa forests closer to the water requirements set out in Table 2. Water use options (Table 4) have been developed on the basis of three main principles:

- programmed water use to address baseflow and small flood requirements
- opportunistic use of water to achieve targets for flow peak magnitude and duration by supplementing ambient peaks in flow
- use of water to mitigate ecological threats associated with peak recession.

The options presented in Table 4 provide specific thresholds, flows and times for water management actions. However these should only be used as a guide to the management actions and to enable water use to be quantified. Actual flow triggers, release rates, durations and timing will vary from year to year according to seasonal flow conditions, environmental water reserves and existing watering commitments.

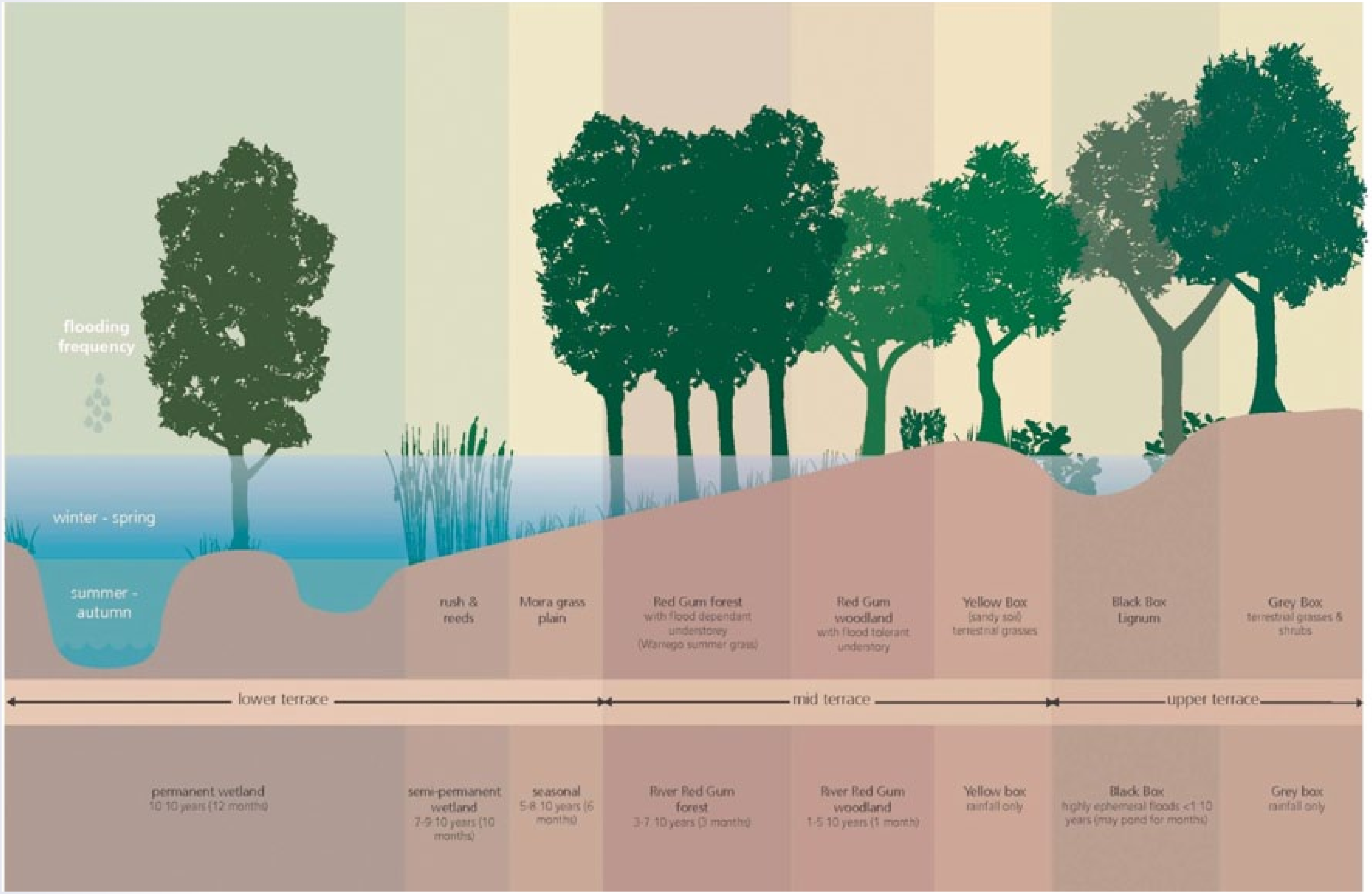

Figure 2: Cross-section of the Barmah-Millewa floodplain showing key vegetation communities and their water requirements (MDBA in prep).

Table 3: Water requirements of key vegetation communities and biota in the Barmah-Millewa Icon Site (MDBA in prep).

Component	Timing	Duration	Frequency	Depth (if critical)	Maximum time between inundation	River flows required (at Yarrawonga)
Giant rush	Winter to mid-summer	7–10 months	7–10 years in 10	Not critical	2 years	4.5–12 GL/d
Moira grass plains	Winter to mid-summer	5–9 months (no more than 10 months) Note: an annual dry period of 2–3 months from late summer to early autumn is needed.	6–10 years in 10	Minimum depth = 0.5 m	3 years	12–25 GL/d
River red gum forest	Winter to spring	3–5 months	4–9 years in 10	Not critical	4 years	15–35 GL/d
River red gum woodland	Winter to spring	1–4 months	3–5 years in 10	Not critical	5 years	35–55 GL/d
Black box woodland	Spring	1–3 months	1–2 years in 10	Not critical	12 years	55–60 GL/d
Breeding conditions for colonial nesting waterbirds (e.g. ibis, spoonbills and egrets).	Spring to summer	4 months (30 GL/d for 3 months, 18 GL/d for 1 month).	3 years in 10	Relatively stable water levels are required, i.e. no sudden reduction in depth.	2 years	18–30 GL/d
Fish: Low-flow specialists Flood-dependent spawners	No specific flows are recommended for fish; consultation with fish ecologists suggests that native fish requirements will be met by those specified for vegetation and waterbirds.					

Table 4: Proposed water use management objectives (all flows are for the Murray River downstream of Yarrawonga).

	Extreme dry	Dry	Median	Wet
Goal	Avoid damage to key ecological assets	Ensure ecological capacity for recovery	Maintain ecological health and resilience	Improve and extend healthy aquatic ecosystems
Water availability	Minimum allocation on record	30th percentile year	50th percentile year	70th percentile year
Watering targets	Provide winter-spring flow in watercourses for at least 30 days.	Provide winter-spring flow in watercourses for at least 50 days. Provide at least one four week fresh over 13,000 ML/d in winter-spring period.	Provide winter-spring flow in watercourses for at least 90 days. Provide at least two four week peaks over 20,000 ML/d in winter-spring period to ensure adequate flooding of the moira grass plains (i.e. Algeboia and Porters Plains) in Moira forest. Provide at least one two week peak over 30,000 ML/d in winter-spring period.	Provide winter-spring flow for at least 120 days. Provide at least 16 weeks of flow over 20,000 ML/d in the winter-spring-summer period. Provide at least eight weeks of flow over 30,000 ML/d in the winter-spring period.
Potential water delivery actions	1. Keep all regulators open in winter-spring period. 2. Release flow to raise river level to 9,000 ML/d to achieve 30 days total before 31 October . 3. Maintain flows down Gulpa Creek (at Offtake) at 850 ML/d to allow filling of Gulpa Creek Wetland Complex and some creek systems within Gulpa Island to achieve 30 days total before 31 October. 4. Maintain flows down Edward River (at Offtake) at 1,600 ML/d to allow filling of some creek systems within Gulpa Island and Millewa forests, and St Helena and Black swamps to achieve 30 days total before 31 October.	1. Keep all regulators open in winter-spring period. 2. Release flow to raise river level to at least 9,000 ML/d to achieve 50 days total before 30 November. 3. Maintain flows down Gulpa Creek (at Offtake) at 850 ML/d to achieve 50 days total before 31 November. 4. Maintain flows down Edward River (at Offtake) at 1,600 ML/d to achieve 50 days total before 31 November 5. If a four week fresh has not occurred before 1 October aim to create or augment a peak to achieve a flow of 13,000 ML/d for 28 days before 15 November. 6. Use reserves to prevent flow peaks from receding too quickly on moira grass plains. 7. Use reserves to augment, prolong or bridge peaks as opportunities arise and circumstances demand.	1. Keep all regulators open in winter-spring period. 2. Release flow to raise river level to at least 12,000 ML/d to achieve 90 days total before 15 December. 3. Release water from Hume to maintain flow above 20,000 ML/d for at least four weeks between August and November. Rely on flood inflows from the Ovens River to superimpose peaks and flow variability. 4. Maintain flows down Gulpa Creek (at Offtake) at >1,000 ML/d to ensure adequate coverage of Gulpa Island, and filling of Gulpa Creek Wetland Complex and through-flows into Moira forest moira grass plains. 5. Maintain flows down Edward River (at Offtake) at >2,000 ML/d to ensure adequate flooding of Gulpa Island and (western) Millewa forests. 6. Use reserves to augment, prolong or bridge peaks as opportunities arise and circumstances demand.	1. Keep all regulators open in winter-spring period. 2. Maintain river flow above 12,000 ML/d from June to October with flood inflows from the Ovens River superimposing flow variability. 3. Use reserves to augment, prolong or bridge peaks as opportunities arise and circumstances demand.

PART 2:
Water Use Strategy

4. Environmental water requirements

4.1 Baseline flow characteristics

Releases or spills from Hume Dam flow downstream to Yarrawonga Weir are contributed to by unregulated Kiewa and Ovens Rivers flows. Under regulated flow conditions, water is diverted at Yarrawonga Weir into both Victoria and New South Wales for irrigation delivery. Downstream of Yarrawonga Weir, flow under regulated flow conditions is constrained in the Murray River at Barmah Choke. The capacity through the Choke is around 8,500 ML/d, which corresponds to a flow downstream of Yarrawonga of around 10,600 ML/d, assuming approximately 2,100 ML/d is diverted at the Edward River and Gulpa Creek offtakes. Below this volume there are some minor effluent creeks activated, but the majority of water remains in-channel unless forest regulators are open. Above this volume, water spills into the Barmah-Millewa forest through various flood runners.

Releases from Hume Dam under regulated flow conditions are constrained by the extent of regulated flow easements in the river downstream of the dam. Current easements allow up to 25,000 ML/d to be passed between Hume Dam and Lake Mulwala without flooding private land.

At higher flow rates of above 30,000 ML/d downstream of Yarrawonga, additional distributary creeks from the Murray River, such as Native Dog, Tuppal and Bullatale Creeks, can commence to flow and become a major source of water entering the Edward River. During large floods, the volume flowing through the Edward-Wakool system can be in the order of five times that flowing through the Murray River.

Flows anticipated in each month under various climate conditions are presented for the Murray River downstream of Yarrawonga in Table 5. In these tables, the 30th percentile flow is the flow that is not exceeded on 30 per cent of all days in each month over the modelled period (i.e. 30 per cent of July days had a flow at d/s Yarrawonga below 5,505 ML/d over the modelled period). Other sites of interest are presented in Appendix B. This information is sourced from the MSM-Bigmod model of the Murray River system with The Living Murray deliveries in place (run #20507). Note: the values in Table 5 are derived independently for each month.

Table 5 shows that minimum flows downstream of Yarrawonga are in the order of 1,800 ML/d, whilst in a wet year flows in spring would be expected to exceed the capacity of the Choke. The similar tables in Appendix B highlight that contributions from the Ovens and Kiewa Rivers to flow at Yarrawonga will be negligible in very dry years. In wet years, the contribution from the Upper Murray, Ovens and Kiewa Rivers will depend on the timing and spatial distribution of individual runoff events and whether Hume Dam is spilling. The contribution from the Ovens River is typically two to four times that from the Kiewa River, which indicates that the Ovens River is more likely to be a source of flood flows along the Murray River than the Kiewa River.

Table 5: Streamflows (ML/d) for the Murray River d/s Yarrawonga (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

4.2 Environmental water demands

In Section 2 of this document, there are separate flow targets proposed for the watercourse, giant rush wetland, moira grass plain and red gum forests. Each of these flow targets is different in different climate years. The volume required to deliver each event will depend on the antecedent conditions in the river and the ability to enhance a natural flood event.

The frequency of the desired flows under current river system operation was estimated using data extracted from the MSM-Bigmod model with the Barmah-Millewa environmental water allowance and The Living Murray water deliveries already in place. The results of this analysis are shown in Table 6, which indicates that a flow of 13,000 ML/d occurs on average every year, but that only around half of those events meet the desired duration of 28 days. This means that the desired 13,000 ML/d event is likely to occur already in median to wet years, but is not likely to occur in dry to very dry years.

Table 6: Average recurrence interval for environmental water demands in Murray River at d/s Yarrawonga Weir, 1895–2009.

Climate year	Event	No. of years in 10 with event of any duration	No. of years in 10 with event of specified duration	Max interval between events of specified duration (yrs)
Very dry	9,000 ML/d for 30 days total from Jun–Oct	10.0	7.5	3
Dry	9,000 ML/d for 50 days total from Jun–Nov	10.0	6.7	3
	13,000 ML/d for 28 days duration from 1 Jun–15 Nov	9.8	5.5	5
Median	12,000 ML/d for 90 days total from 1 Jun–15 Dec	9.8	2.8	13
	20,000 ML/d for 28 days duration from Aug–Nov	7.7	3.4	10
	20,000 ML/d for 2 events of 28 days duration from Jun–Nov	7.9	2.6	22
	30,000 ML/d for 14 days from Jun–Nov	6.2	3.5	10
Wet	12,000 ML/d from Jul–Oct (triggered in Jun)	9.6	1.1	19
	20,000 ML/d for 112 days (16 wks) total from Jun–Feb	8.0	1.1	22
	30,000 ML/d for 56 days total from Jun–Nov	6.2	1.1	22

Wet Year Environmental Water Demand

The environmental flow objective in a wet year is to provide an average flow of 12,000 ML/d downstream of Yarrawonga from the start of June to the end of October, which is a period of five months. The provision of this event is assumed to be triggered by a natural event of 12,000 ML/d occurring any time in June, which based on modelled data at downstream of Yarrawonga, occurs on average four years in 10. This is only slightly more frequent than the broad definition of a wet year, which is defined as the conditions exceeded on average three years in 10.

The volume required under these assumptions averages 175,000 ML/yr in a wet year and is up to 654,000 ML/yr, as listed in Table 7. Even though the wet year event is triggered in four years out of 10, environmental water is only required to supplement flows in 3.2 years out of 10. As stated previously, this shortfall is based on hydrologic data from MSM-Bigmod which has the Barmah-Millewa allowance and The Living Murray deliveries already in place, so the volumes in Table 7 are in addition to deliveries under those other environmental flow allowances.

Table 7: Range of event volumes to achieve desired environmental flows in a wet year.

Climate year	Event	No. of years in 10 event is triggered	Average volume provided in given climate years (GL/yr)	Maximum volume provided (GL/yr)
Wet	12,000 ML/d from July to October (triggered in June)	4.0	175	654

Very Dry to Medium Year Environmental Water Demand

The environmental water demand in very dry to medium climate years is assumed to be triggered by the number of days that the flow downstream of Yarrawonga has been above certain thresholds from 1 June to 15 September. The triggers for defining which event is to be provided are as follows:

If flow > 9,000 ML/d for more than 50 days – medium year events to be provided

If flow > 9,000 ML/d for 30 to 50 days – dry year events to be provided

If flow > 9,000 ML/d for less than 30 days – very dry year events to be provided.

In each case, the wet year trigger in June, discussed in the previous section, would take precedence over these flow triggers. These events would not be provided if the wet year trigger has already been activated in June.

The volume of water required for each type of event in the given climate years is shown in Table 8. This table shows, for example, that the volume of water required to deliver the desired event in a very dry year averaged 12 GL/yr when provided, but up to a maximum of 117 GL/yr could be required in any given very dry year. Modelled data indicated that the 9,000 ML/d event in a dry year was always provided naturally by the end of November and did not require additional water from environmental entitlements. For the two event types in a dry or median year, the average volume required is the sum of the two event volumes (e.g. in a median year an average of 10+74=84 GL/yr is required and in a dry year an average of 0+39=39 GL/yr is required). This is because the shortfall for the larger event in a dry or median year is calculated assuming that the shortfall for the smaller event is already provided by delivery of environmental flows. Maximum volumes are not necessarily additive, as they may occur in different years for the two event types.

Table 8: Range of event volumes to achieve desired environmental flows in a very dry to median year (calculated at downstream of Yarrawonga).

Climate year	Event	No. of years in 10 event is triggered	Average volume provided in given climate years (GL/yr)	Maximum volume provided (GL/yr)
Very dry	9,000 ML/d for 30 days total from Jun–Oct	2.9	12	117
Dry	9,000 ML/d for 50 days total from Jun–Nov	1.9	0	0
	13,000 ML/d for 28 days duration from 1 Jun – 15 Nov		39	111
Median	12,000 ML/d for 90 days total from 1 Jun – 15 Dec	1.2	10	75
	20,000 ML/d for 28 days duration from Aug–Nov		74	264

4.3 Summary of Environmental Water Demands

Environmental water demands from the range of proposed events are shown in Table 9. This table indicates that the volume required to supply all of the proposed events averages 76 GL/yr but could range from no requirement to over 600 GL/yr in any given year. Demands for water are significantly greater in median to wet years than in dry to very dry years.

Table 9: Range of event volumes to achieve desired environmental flows across all climate years.

Climate year	Minimum annual volume in given climate years (GL/yr)	Maximum annual volume in given climate years (GL/yr)	Average annual volume in given climate years (GL/yr)	Average annual volume, averaged over all climate years (GL/yr)
Very Dry	0	117.1	12	3.6
Dry	0	110.0	39	7.2
Median	0	339.3	84	10.3
Wet	0	653.7	75	55.7
All years	**0**	**653.7**	**n/a**	**76.7**

The effect of the proposed environmental flow recommendations on the average and maximum interval between events is shown in Table 10. This table shows, for example, that by using environmental water in the manner proposed, the frequency of years with flows above 12,000 ML/d from July to October, which are associated with flow objectives in a wet year, could be increased from one in 10 years to four in 10 years and the maximum interval between events could be reduced from 19 years to eight years. As stated previously, these results are based on hydrologic data from MSM-Bigmod which has the Barmah-Millewa allowance and The Living Murray deliveries already in place, so the current recurrence intervals in Table 10 already include these other events.

Table 10: Change in recurrence intervals under proposed watering regime.

Climate year	Event	No. of years in 10 with event		Maximum interval between events (years)	
		Current	Proposed	Current	Proposed
Very dry	9,000 ML/d for 30 days total from Jun–Oct.	7.5	7.8	3	3
Dry	9,000 ML/d for 50 days total from Jun–Nov.	6.7	7.3	3	3
	13,000 ML/d for 28 days duration from 1 Jun – 15 Nov	5.5	6.8	5	4
Median	12,000 ML/d for 90 days total from 1 Jun – 15 Dec.	2.8	4.7	13	8
	20,000 ML/d for 28 days duration from Aug–Nov	3.4	4.0	10	10
	20,000 ML/d for 2 events of 28 days duration from Jun–Nov.	2.6	2.7	22	21
	30,000 ML/d for 14 days from Jun–Nov	3.5	3.5	10	10
Wet	12,000 ML/d from Jul–Oct (triggered in Jun).	1.1	4.1	19	8
	20,000 ML/d for 112 days (16 wks) total from Jun–Feb.	1.1	1.1	22	22
	30,000 ML/d for 56 days total from Jun–Nov.	1.1	1.1	22	22

5. Operating regimes

5.1 Introduction

This section presents suggested operational triggers for the implementation of environmental flow proposals. These triggers should be used as a guide and refined based on operational experience after watering events. Operational water delivery involves several steps, including:

- Identifying the target environmental flow recommendations for the coming season
- Defining triggers to commence and cease delivering those recommended flows
- Defining triggers for opening or closing environmental flow regulators
- Identifying any constraints on 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 target environmental flow recommendations

The selection of target environmental flows in each of the different climate years is triggered by flows in the Murray River downstream of Yarrawonga, as shown in Table 11. The selection of a wet year is triggered first by any event in June greater than or equal to 12,000 ML/d. If this trigger does not occur, then the selection of whether to aim to deliver very dry, dry or median year flow recommendations is based on the number of days that the flow is above 9,000 ML/d downstream of Yarrawonga. If the flow has been above 9,000 ML/d for more than 30 days over this period, then the very dry recommendations will have already been met without the need for environmental water deliveries. Similarly, if greater than 9,000 ML/d has occurred for at least 50 days, then one of the dry flow recommendations will have been met, so environmental water managers may instead aim to provide the median year recommendations.

If flow conditions change rapidly, such as in a major rain event, consideration should be given to aiming for higher volume events associated with a wetter climate year. The selection of target flows should be flexible and in response to conditions in the Murray River, because the flow thresholds for achieving the ecological benefits aligned with each threshold (particularly for the higher flow events) are not precise.

Table 11: Identifying seasonal target environmental flow recommendations.

Climate year for selecting flow recommendations	Flow in Murray River d/s Yarrawonga (ML/d)
Very dry	>9,000 ML/d for <30 days from 1 Jun to 15 Sep
Dry	>9,000 ML/d for 30–50 days from 1 Jun to 15 Sep
Median	>9,000 ML/d for >50 days from 1 Jun to 15 Sep
Wet	>12,000 ML/d in Jun

The above triggers may be further refined to minimise the volume of water required relative to the ecological benefit derived from watering. If the trigger for a wet year, event of 12,000 ML/d at any time in June, is used then the event occurs slightly more frequently than the defined wet year frequency of three years in 10 and very large volumes of water are required in some years. Additional triggers to restrict the start of the event could be developed based on either the allocation in July and carryover available or a higher threshold flow in June. A flow trigger to cease providing the event could also be developed to avoid providing excessive volumes of water if the high flow in June is followed by a very dry July to October period. This exit trigger could be based on either a cumulative shortfall since June, or a minimum flow anticipated without the flow supplements, or the proportion of time below the target flow without the flow supplements. The exit trigger could also be based on ecological triggers such as the occurrence of fish spawning events.

For example, the trigger to determine a wet year starting in June could be refined by including the additional requirement that NSW and Victorian Murray allocations result in a combined total of 4,000 GL being made available for use to all entitlement holders in June. A threshold of 4,000 GL was selected because above this threshold modelling results indicated there was a low likelihood of low allocations at the start of July. If this threshold were to be adopted, environmental water would be used in fewer years (around 2.5 years in 10 instead of 3.2 years in 10) and an average of 43 GL/yr would be required instead of 56 GL/yr. The average and maximum volume required in designated wet years would not change.

A higher flow threshold to trigger the wet year event was also examined to see if it could reduce the delivery volume required without reducing the frequency of events to below three years in 10. With a higher flow threshold of 20,000 ML/d to trigger the 12,000 ML/d wet year baseflow, the average volume required would be only 29,000 ML/yr and the maximum volume required would be 504,000 ML/yr. Therefore environmental water for this type of event would only be used in two years out of 10 instead of 3.2 years in 10.

Similarly, if a trigger were to be adopted which ceases providing the 12,000 ML/d event when flow would have dropped to below 3,000 ML/d without watering, then the average volume provided would be 48,000 ML/yr, but the maximum volume provided would drop to 526,000 ML/yr. Operationally, adopting such a trigger would require the ability to estimate flow in the river without environmental water releases, which would require close collaboration with MDBA river operators and would be expected to occur for all watering events.

These examples show that the triggers for entering and exiting this wet year event can be manipulated to conserve the volumes released and to make the provision of this event align with the desired frequency of 3 years in 10.

For all event triggers, reference should be made to seasonal forecasts from the Bureau of Meteorology to assess the likelihood of wet conditions continuing after the June flow trigger has been reached. Seasonal climate forecasts from the Bureau are available at http://www.bom.gov.au/climate/ahead/rain_ahead.shtml and seasonal streamflow forecasts are available at http://www.bom.gov.au/water/ssf/.

5.3 Delivery triggers

Proposed operational triggers for delivering the suggested environmental flow proposals are presented in Table 12. The first trigger is the wet year trigger, as discussed previously. Environmental water managers may consider ceasing the delivery of this event if the 12,000 ML/d peak in June is isolated and conditions from July onwards are dry. Specific triggers for ceasing this event are to be developed.

As discussed above, the delivery of very dry to median year recommendations is triggered on 15 September. After this date, it is assumed that environmental water managers would make a decision either to extend naturally occurring freshes or to create those freshes. In Table 12 it is assumed that environmental water managers would choose to extend naturally occurring events where they are within 10 days of the desired duration. For example, in a very dry year, any naturally occurring events above 9,000 ML/d downstream of Yarrawonga would be observed. Where they are estimated to drop below 9,000 ML/d after 20–29 days total time above the threshold since June, environmental water would be used to prolong the event to the desired duration. The likelihood of high river flows increases as the winter and spring season continues (see Table 5 in the previous section), so the later that environmental water managers can delay the provision of water, the more likely that the desired events will occur naturally. If the target events do not occur naturally, then environmental water managers can start providing the event from releases at the nominated start date in Table 12, to finish the event just before the end of the specified season for delivery. For example, in the very dry year, if flows greater than 9,000 ML/d do not occur naturally for at least 20 days, prior to 1 November, then environmental water would make up the shortfall by providing 9,000 ML/d from this date until the 30 day total is reached.

For the longer duration event of 12,000 ML/d for 90 days in a median climate year, the last date at which environmental water deliveries can occur will depend on how many days the flow has been above this threshold to date. For example, if the flow has been above 12,000 ML/d for 60 days from 1 June, then the last date at which delivery of the remaining 30 days could commence is 15 November, otherwise 90 days above this threshold would not be provided within the recommended delivery window, which ends on 15 December.

For the median year, two 28 day events are recommended. It is assumed that a short period (notionally 14 days) of independence is required for these to be recognised as independent events.

For the wet year, the window for delivery of flows above 20,000 ML/d is long (eight months), so it is difficult to make decisions about whether to augment naturally occurring high flows during the year. It is also likely that this event would take place in conjunction with environmental flow delivery to the Edward-Wakool system. The 30,000 ML/d event will be largely unregulated, but can be enhanced by releasing environmental water from Hume Dam if it is not spilling, subject to downstream flooding constraints discussed later in this section. In both cases, given the potentially large volumes of water involved and the potential for interaction with other delivery plans, it is recommended that the trigger for making releases for these recommendations be assessed in more detail prior to the delivery occurring.

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

Climate year	Flow objective in Murray River d/s Yarrawonga Weir	Season/ timing	Average return period	Trigger for delivery	Trigger for ceasing delivery
Very dry	9,000 ML/d for 30 days total.	Jun–Oct	All very dry years.	Commence delivery if: - Flow d/s Yarrawonga > 9,000 ML/d for at least 20 days; or - By 2 Oct. Whichever occurs earlier.	n/a
Dry	9,000 ML/d for 50 days total.	Jun–Nov	All dry years.	Commence delivery if: - Flow d/s Yarrawonga > 9,000 ML/d for at least 40 days; or - By 10 Oct. Whichever occurs earlier.	n/a
	13,000 ML/d for 28 days duration.	1 Jun – 15 Nov		Commence delivery if: - Flow d/s Yarrawonga > 13,000 ML/d for at least 18 days; or - By 15 Oct. Whichever occurs earlier.	n/a
Median	12,000 ML/d for 90 days total.	1 Jun – 15 Dec	All median years.	Commence delivery if: - Flow d/s Yarrawonga >12,000 ML/d for at least 80 days; or - By last date prior to 15 Dec to achieve 90 days total above threshold. Whichever occurs earlier.	n/a
	20,000 ML/d for 28 days duration (1st event).	Aug–Nov		Commence delivery if: - Flow d/s Yarrawonga > 20,000 ML/d for at least 18 days; or - By 15 Sep. Whichever occurs earlier.	n/a
	20,000 ML/d for 28 days duration (2nd event).	Aug–Nov		Commence delivery after minimum 14 day period of independence from first 20,000 ML/d event if: - Flow d/s Yarrawonga > 20,000 ML/d for at least 18 days; or - By 1 Nov. Whichever occurs earlier.	n/a
	30,000 ML/d for 14 days.	Jun–Nov		Commence delivery if: - Flow d/s Yarrawonga > 30,000 ML/d; or - By 15 Nov. Whichever occurs earlier.	n/a
Wet	12,000 ML/d.	Jul–Oct	All wet years.	Commence delivery if: - Flow d/s Yarrawonga > 12,000 ML/d in Jun.	Consider ceasing for ongoing dry conditions occur from Jul–Oct
	20,000 ML/d for 112 days (16 wks).	Jun–Feb		Commence delivery opportunistically in conjunction with Edward-Wakool system watering.	
	30,000 ML/d for 56 days total.	Jun–Nov		Commence delivery opportunistically in conjunction with Edward-Wakool system watering.	

In some cases the rules assumed in preparing the likely hydrograph under the proposed watering regime could be further optimised. It is stated in Table 12, for example, that flows should be delivered when they are within 10 days of the desired number of days above the nominated flow threshold. This assumes that extending these naturally occurring events will require smaller volumes than taking the risk that the event will occur naturally later in the season. At this stage, the 10 day shortfall duration is arbitrary and it may be that a slightly longer or shorter shortfall duration provides the same ecological outcome with less use of environmental allocations. This issue of optimising the delivery of events warrants further investigation.

The integration of water delivery to achieve multiple ecological outcomes also needs further investigation. For the Barmah-Millewa median year recommendations, for example, if the period of flows above 12,000 ML/d is being extended by environmental water deliveries, then environmental water managers may deviate from the above triggers to provide the 20,000 ML/d event at the same time, rather than waiting until 1 November.

Similarly, integration of water delivery with the Edward-Wakool system in particular needs to be considered. This is discussed later in this chapter and warrants further investigation.

5.4 Forest regulators

The operation of the forest regulators is important for delivering flows to the forest in the flow range up to the capacity of the Choke (10,600 ML/d at d/s Yarrawonga). The environmental flow options in Table 4 suggest keeping all wetland regulators open during the winter to spring period from June to November. The implications of this on river operations and environmental flow delivery volumes are not currently well understood.

There are various wetland regulators located throughout the Barmah-Millewa forest. The capacity of the regulators is shown in Table 13. This table illustrates that the commence to flow threshold ranges from 3,000 ML/d, which is well below the typically irrigation season flow through the Choke, to around 9,000 ML/d. The highest capacity regulator into the Millewa forest is Mary Ada on Toupna Creek and the highest capacity regulator into Barmah forest is the Gulf Creek regulator on Gulf Creek.

Table 13: Forest regulator capacities.

Regulator name	Wetland/creek system	State	Murray River commence to flow (ML/d)	Capacity at low Murray River flows (ML/d)
Mary Ada	Toupna Creek	NSW	3,500	2,800
House Creek	House Creek	NSW	6,000	630
Pinchgut Creek	Pinchgut Creek	NSW	4,500	375
Nestrons	Douglas Swamp	NSW	4,500	240
Walthours	Walthours Wetland	NSW	4,500	90
n/a	Duck Lagoon	NSW	~4,700 to provide Gulpa Ck flow of 400	unknown
n/a	Reed Bed orth Wetland	NSW	~4,500 to provide Gulpa Ck flow of 370	unknown
n/a	Reed Bed South Wetland	NSW	~4,500 to provide Gulpa Ck flow of 370	unknown
Horse-shoe Lagoon	Horse-shoe Lagoon	NSW	unknown	unknown
Crumps	St Helena	NSW	unknown	unknown
Black Swamp	Black Swamp	NSW	unknown	unknown
Sandpit Regulator	Smiths Creek	VIC	9,000	340
Gulf Regulators	Gulf Creek	VIC	3,000	2,400
Stewarts Kitchen	unknown	VIC	9,000	20
Bull Paddock	unknown	VIC	9,000	40
Punt Paddock Creek	unknown	VIC	8,000	90
Big Wood cutter	unknown	VIC	7,500	90
Boals Creek	Boals Creek	VIC	5,000	90
Sapling Creek	Sapling Creek	VIC	7,500	40
Island Creek	Island Creek	VIC	7,500	40

Source: MDBA (2010c).

5.5 Storage releases

The release capacity of Hume Dam is well in excess of the downstream constraints on releases due to flooding of private land. The physical release capacity of Hume Dam is therefore not a constraint on delivery of water for the environment. Yarrawonga Weir is also not a constraint in delivering environmental flows downstream of the weir.

Releases from Hume Dam typically increase as the irrigation season progresses and will therefore ordinarily be higher in summer than early spring, for example. Transfers to Lake Victoria from Hume Dam can occur prior to peak irrigation demand periods in years when Lake Victoria or the Menindee Lakes are low and are not expected to fill from other sources. The raising of Murray River baseflows by the MDBA outside of peak irrigation periods may provide opportunities to deliver environmental flows to the Barmah-Millewa forests with smaller volumes of environmental allocations. Environmental water managers should therefore liaise with the MDBA prior to a spring watering to see whether transfers to Lake Victoria are likely to occur and whether their timing can be adjusted to coincide with environmental water delivery to the forest (or vice versa).

5.6 Flood easement constraints

The Murray River channel capacity at Albury corresponds to a water level of 3.1 m at the Albury flow gauge. Beyond this level, flooding of private land can occur in the Murray River reach from the Junction with the Kiewa River to Yarrawonga Weir. This water level is equivalent to a flow in the Murray River at Doctors Point of approximately 25,000 ML/d, which is the maximum target flow for Hume Dam operators. Above this level (and below the minor flood level at Albury), flood pre-releases are sometimes made. When this occurs, the MDBA liaises with affected landholders via the Murray River Action Group (MDBA 2010c).

Table 14: Flood Levels Downstream of Hume Dam (MDBA 2010c).

Site		Channel capacity	Minor	Moderate	Major
Doctors Point (gauge no. 409017)	Gauge (m)	3.8[1]	5.50	6.50	7.0
	Flow (ML/d)	25,000	54,100	114,000	186,000
Albury (gauge no. 409001)[2]	Gauge (m)	3.1	4.30	4.90	5.50
	Flow (ML/d)	25,000	45,400	71,600	139,000

1 From rating table on Victorian Data Warehouse, accessed 1/4/11 (http://www.dse.vic.gov.au/waterdata/)

2 The Albury gauge is not rated for flow because the Wodonga Creek anabranch is not gauged. Flow values are estimated by the MDBA based on relationship between Albury gauged level and Doctor's Point flow.

5.7 Travel time

The travel time along the Murray River and Victorian tributaries was examined in some sample runoff events to identify the ability of environmental water managers to order releases to piggyback natural runoff events. The travel time along the Murray River from downstream of the Kiewa River confluence below Hume Dam (Doctor's Point) is estimated to be around two days to Corowa (above the Ovens River confluence) and around four days to downstream of Yarrawonga. These travel times are based on Murray River flows in the flow range corresponding to Barmah-Millewa watering events of up to 30,000 ML/d, as shown by way of example for two events in 1994 in Figure 3. In this event, the contribution from the Victorian tributaries was reasonably constant and did not influence travel times.

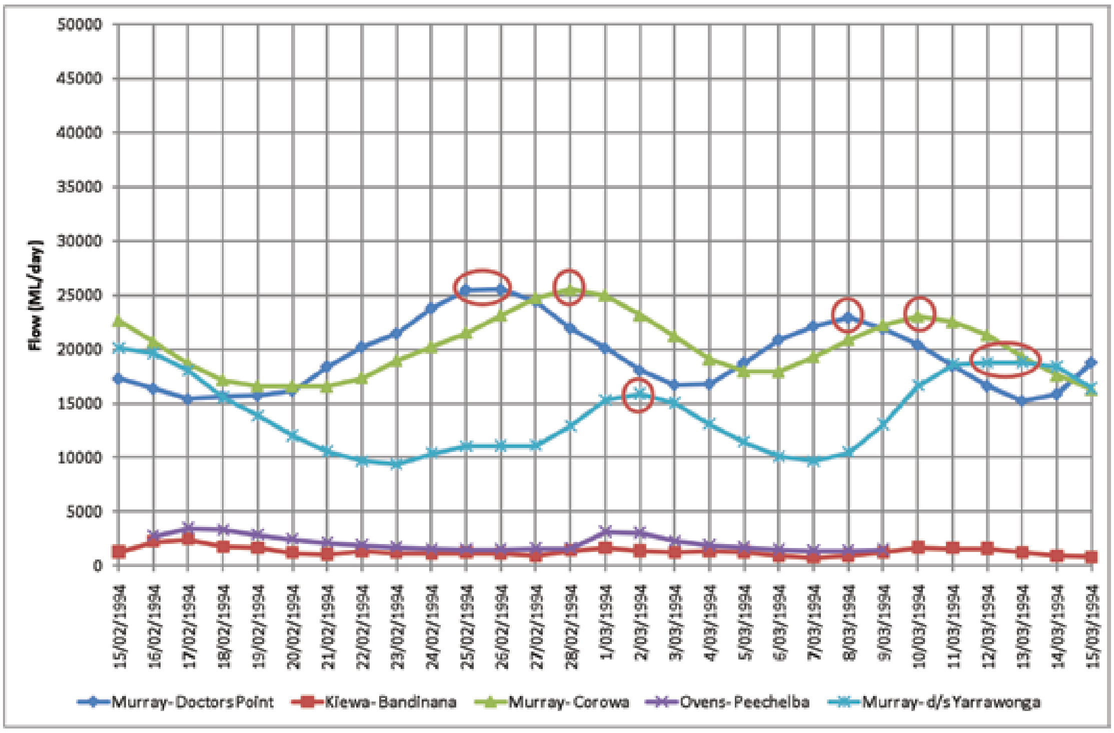

Figure 3: Travel time from Hume Dam to d/s Yarrawonga (Feb–Mar 1994 event, 10–20,000 ML/d d/s of Yarrawonga).

For higher flow events, when the Edward-Wakool and Barmah-Millewa sites are being watered concurrently, travel times will be slightly longer at around six days from Hume Dam to downstream of Yarrawonga, as shown for the 45,000 ML/d event in Figure 4. In this event the contribution from the Victorian tributaries was reasonably constant and did not influence travel times.

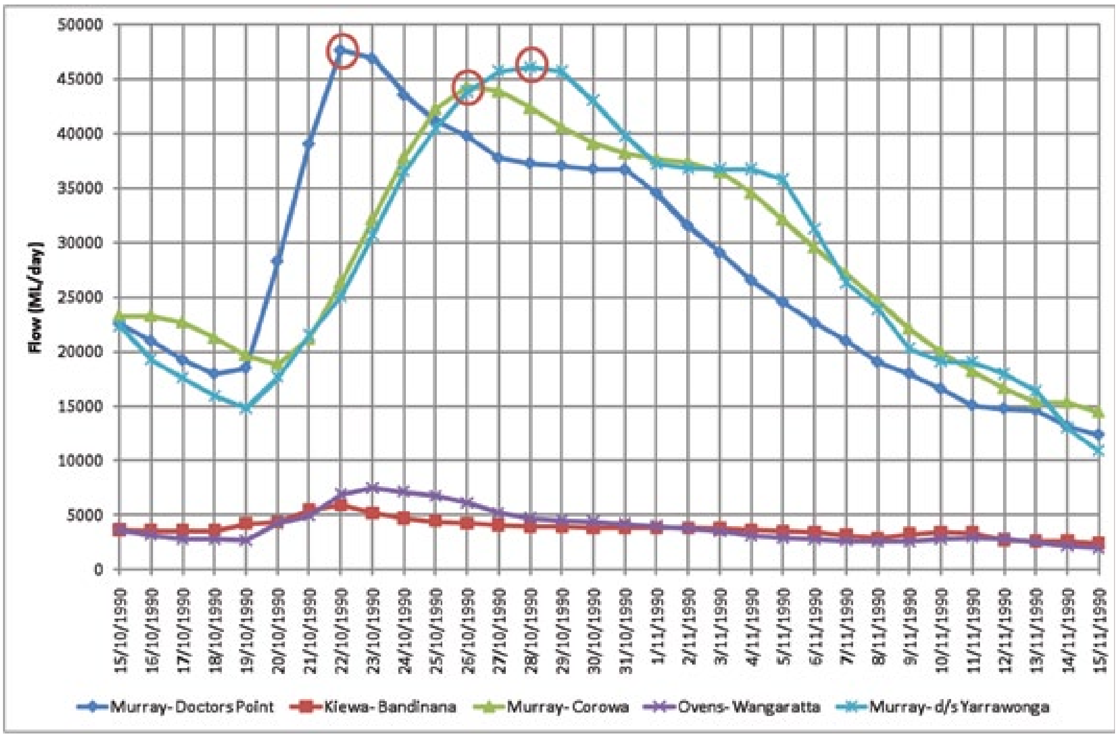

Figure 4: Travel time from Hume Dam to d/s Yarrawonga (Oct–Nov 1990 event, 45,000 ML/d d/s Yarrawonga).

The travel time from the Ovens River outlet at Peechelba East to the Murray River downstream of Yarrawonga is approximately one day. As noted previously, the Ovens River is the main tributary inflow between Hume Dam and Yarrawonga and contributes significantly more flow than the Kiewa River and other smaller creeks. Figure 5 illustrates this travel time during an event when the Ovens River was contributing the majority of the Murray River flow and releases from Hume Dam were small in comparison.

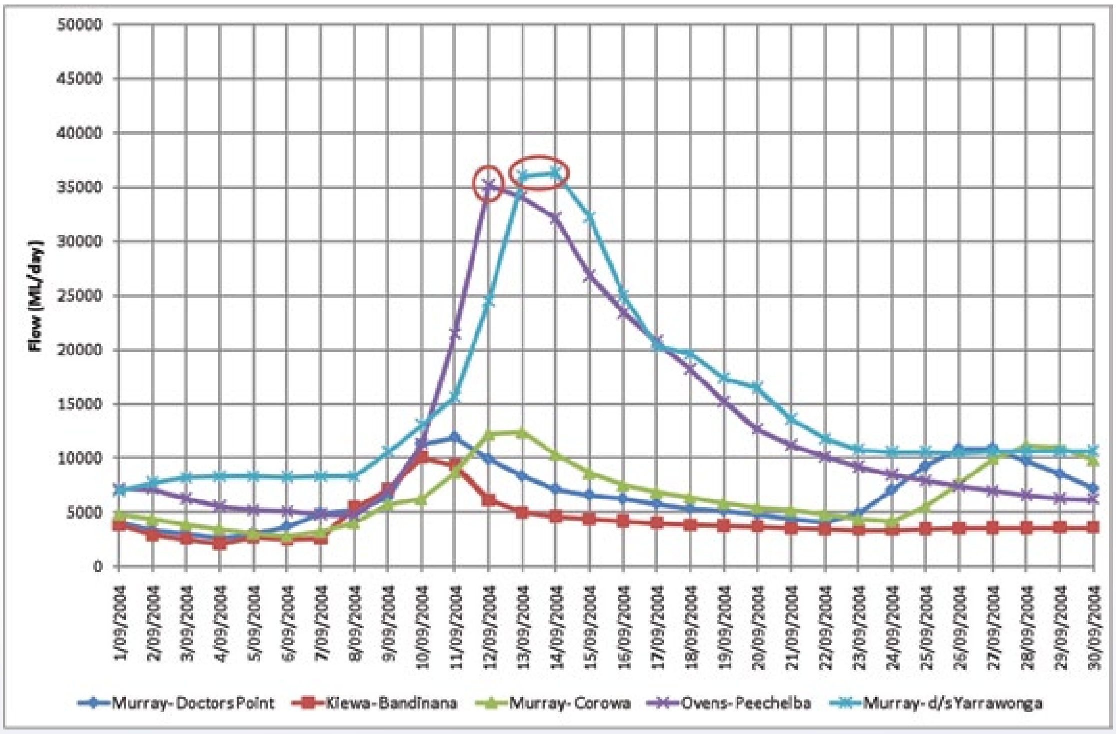

Figure 5: Travel time from Peechelba to d/s Yarrawonga (Sep 2004 event, 35,000 ML/d d/s Yarrawonga).

These travel times mean that if environmental water managers want to piggyback onto a natural runoff event from the Ovens River, then any releases from Hume Dam will need to be released around three days in advance of the target flow at Peechelba in order for the Ovens and Murray flows to reach Yarrawonga at the same time. If Ovens River events are of longer duration (i.e. greater than three days) then the release of water from Hume Dam can be based on anticipated recession flow behaviour on the Ovens River at Peechelba, which will follow an exponential decline in the absence of rainfall.

If the Ovens River events are of shorter duration, then indicator gauges further upstream may be needed. Figure 6 shows travel time along the Ovens River during selected runoff events from 1993. This figure indicates that one to two days advance notice of the event at Peechelba can be gained by looking at the flow data at Wangaratta. The Peechelba events are less easily identifiable further upstream at Myrtleford and Bright, presumably because of contributions from the King River.

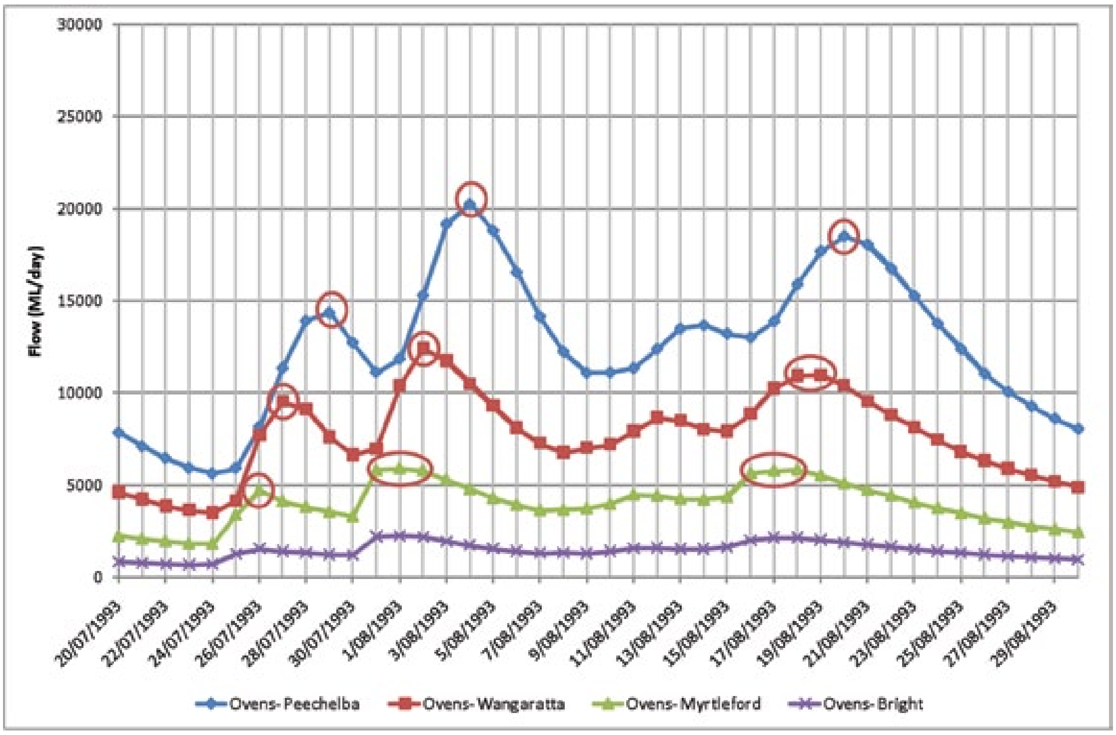

Figure 6: Travel time along the Ovens River (Jul–Aug 1993 events, 15–20,000 ML/d at Peechelba).

The travel time under regulated flow conditions from Yarrawonga to Torrumbarry Weir is around seven days. There was insufficient data at the time of writing this document to comment on the travel time during the 2010 watering. There is limited concurrent flow data along the Murray River between Yarrawonga upstream of the forest and Barmah downstream of the forest. The travel time in a higher example runoff event (Figure 7) in 1984 was 13 days for the August event, and around 10 days in the subsequent September/October event. This suggests that travel time drops if the floodplain has recently been watered. The flow in this event is significantly attenuated due to flood breakouts into the Edward-Wakool system and movement of water through the Barmah-Millewa forest.

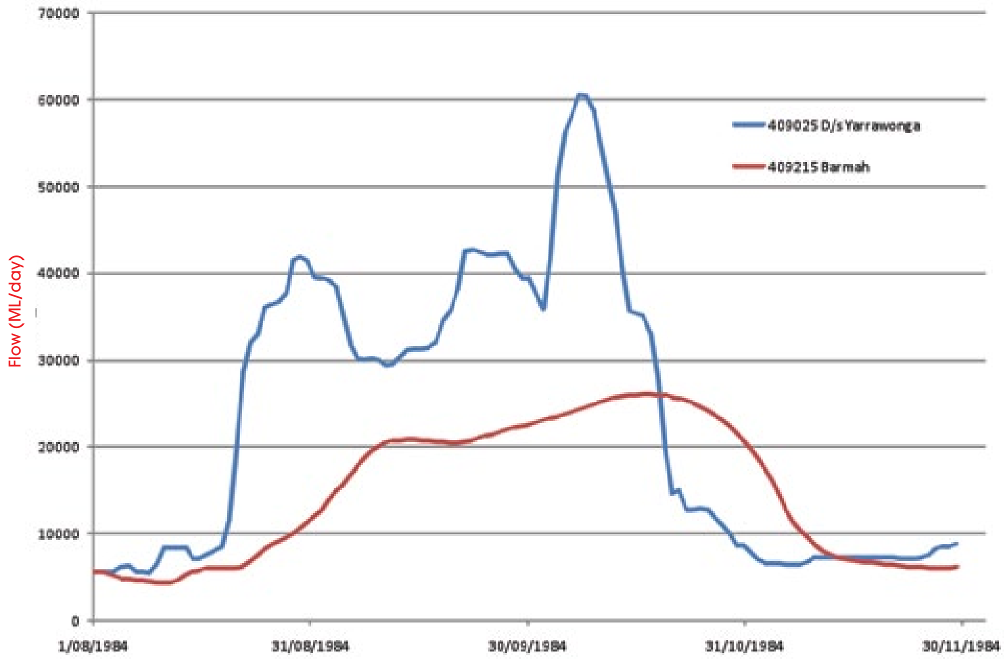

Figure 7: Travel time from Yarrawonga to Barmah (Aug–Oct 1984 events, 30–60,000 ML/d d/s Yarrawonga).

5.8 Other accounts and reserves

There are a number of sources of environmental water for the Barmah-Millewa forest, including State environmental water entitlements (e.g. the Victorian Murray Flora and Fauna Bulk Entitlement) and shared environmental entitlements, including water recovered through the Living Murray program and through the Australian Government's *Water for the Future* program. In addition, Barmah-Millewa forest has its own Barmah-Millewa Environmental Water Allowance (EWA). The delivery of water to Barmah-Millewa forest is likely to achieve better ecological outcomes when undertaken as an integrated approach.

Barmah-Millewa Environmental Water Allowance (EWA)

The Barmah-Millewa EWA is a rules-based allocation that was established in 1993. The Murray-Darling Basin Ministerial Council authorised a high security environmental water entitlement of 100,000 ML/year, to be drawn equally from the States of Victoria (pro-rata with Victorian high security allocations) and NSW[1] (once NSW high security allocations reach 97 per cent), and a low security allocation of 50,000 ML (again to be contributed equally from Victoria and New South Wales), to be provided in years when the Victorian irrigation allocation exceeds 130 per cent.

1 The NSW component of the Barmah-Millewa Commonwealth Environmental Water Allowance (EWA) is also noted under *Water Management Act 2000* (*NSW*). The Water Sharing Plan for the Murray and Lower Darling Regulated Rivers Water Sources (Water Sharing Plan) defines the EWA rules (S. 15) and the conditions under which it may be used for the forests or, conversely, borrowed for consumptive water use. As a provision under the Water Sharing Plan, and because the EWA affects the bulk water supply of the NSW Murray River Water Source, the use and management of the EWA is subject to audit and review.

The Victorian Murray Bulk Entitlement process provided for agreement for management of the Victorian component, including an increased allocation, accrual in storage, triggers for release, and loaning in dry times.

The EWA can be carried over in storage to a maximum of 700,000 ML (Bulk Entitlement). The EWA was first used in 1998, when 98,000 ML was released. Since then, releases have been made in 2000 (341,000 ML), 2005 (513,000 ML), and 2010–2011 (428,000 ML)

'Annual alternating' Arrangements

High river flows now often occur outside the natural flooding period (May to mid-December) for the Barmah-Millewa icon site. These increased river flows usually arise from the rain rejection of pre-ordered irrigation supplies and typically cause Murray River flows to increase from near forest channel capacity of about 10,400 ML/d to a flow of 12,000 to 15,000 ML/d or more, for a period of five to seven days.

To minimise the impacts of unseasonal flooding on each side of the river, NSW and Victoria have agreed to implement 'alternating' arrangements for taking the increased flows. Barmah takes unseasonal flows in 'even' years and Millewa takes these flows in 'odd' years.

This co-operative arrangement has allowed the wetlands in each State a better chance of drying every second year, and thereby has assisted in returning to a more natural flood and drying regime. However, during extended low flow periods, as has been recently experienced, it may be advantageous to accept flows at any time.

Consumptive Water en route

There may be opportunities to maximise environmental benefits for Barmah-Millewa forest through the transfer of consumptive water to downstream users and Lake Victoria. This may be sufficient to generate flows through low lying creeks within the forests. Consumptive water can also be used in tandem with environmental water to improve ecological outcomes for the forest. For example, environmental water can be 'piggybacked' on irrigation flows to create higher flows in-river to water low-lying wetlands and red gums, which could not be achieved by releases of environmental water alone.

State and Australian Government-based Environmental Entitlements

State based environmental entitlements from Victoria and NSW can be used in the Barmah-Millewa forest, including the Victorian Murray Flora and Fauna Bulk Entitlement (27,600 ML high security) and the NSW Adaptive Environmental Water (32,027 ML). These entitlements can also be used at other sites along the Murray River.

In addition to State-based entitlements, water has been set aside for the environment under the Living Murray program.

5.9 Interaction with other assets of the Murray-Darling Basin

Water management in the Yarrawonga to Tocumwal and Barmah-Millewa system and Edward-Wakool systems is closely linked.

The Edward-Wakool system is located downstream of, and adjacent to, the Barmah-Millewa forest and receives inflows via the Edward River and anabranches that cross the Millewa forests. Therefore the flooding regime in Barmah-Millewa forest dictates the inflow regime of the Edward-Wakool system. Similarly, the water requirements of the Edward-Wakool system cannot be provided independently of water management in Barmah-Millewa.

The fundamental water requirements of the two systems are similar. Both require baseflow to be provided in winter and spring, freshes to be provided in spring, and overbank flows to inundate floodplain communities. The thresholds differ because of the water entering Barmah-Millewa, only a portion flows to the Edward-Wakool system and the remainder flows to the Murray River. Water strategies for the two sites have been developed with their similar requirements in mind. Nevertheless further investigation is required to improve co-ordination of environmental water delivery across these two systems, as well as sites further downstream.

The commence to flow volumes for the effluent creeks into the Edward-Wakool system downstream of Yarrawonga are approximately 3,500–10,500 ML/d for the Millewa forest creeks, up to 33,000 ML/d for Native Dog Creek, 50,000 ML/d for Bullatale Creek and 100,000 ML/d for Tuppal Creek based on flow in the Murray River downstream of Yarrawonga (SKM 2006). However, gauging information presented in the Edward-Wakool environmental water delivery document suggests that the commence to flow threshold for Bullatale Creek may be lower than the reported 50,000 ML (SKM 2006). Toupna Creek is the main creek running through the Millewa forest and has a commence to flow threshold in the Murray River downstream of Yarrawonga of around 3,500 ML/d with the Mary Ada regulator open, and a regulated flow capacity of 2,800 ML/d. With the regulator closed, flows in the Murray River downstream of Yarrawonga must increase to around 10,500 ML/d for this creek to flow.

The commence to flow threshold for the main effluent creeks upstream of the Millewa forest is above the majority of the target flows specified in the environmental flow recommendations in this report. This means that the delivery of the target environmental flows of 9,000–30,000 ML/d is unlikely to result in significant forfeit to the Edward-Wakool system prior to reaching the forest.

Water passing down the main stem of the Murray River potentially contributes to the water requirements of Koondrook-Perricoota, Gunbower forest, Hattah Lakes, Mulcra Island, Lindsay Island, Chowilla, the South Australian weir pools and the Coorong and Lower Lakes. The significant attenuation of flows through the Barmah-Millewa forest suggests that Murray River water from a managed Barmah-Millewa watering could in the future possibly provide return flows for a Gunbower / Koondrook-Perricoota watering through their forest regulators or establish baseflows on which to superimpose flood pulses from the Goulburn River.

5.10 Water delivery costs

5.10.1 Delivery Costs

State Water's delivery costs for 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 of $2.32/ML. See the following reference for details: http://www.statewater.com.au/Customer+Service/Water+Pricing. State Water also incurs charges for water delivered via the MIL escapes of $1.50/ML. Use of the MIL system incurs a water forfeit of 10 per cent.

There are currently no delivery costs if Victorian water shares are delivered via the river system, however delivery and storage charges are subject to review on an annual basis and additional fees and charges may apply. More information is available from http://g-mwater.com.au/customer-services/feesandcharges.

5.10.2 Regulated river water management charges

The NSW Office of Water also charges water users to recover a share of the costs incurred for providing water management services, including managing the quantity and quality of water available to water users. In 2011–12, these charges for the NSW Murray system were $0.90/ML for usage and $1.38/ML of entitlement/unit share.

See http://www.water.nsw.gov.au/Water-management/Law-and-policy/Water-pricing/Water-management-charges/Water-management-charges/default.aspx for more information.

5.10.3 Carryover costs

State Water does not charge for carryover.

Goulburn-Murray Water does not charge for carryover up to 100 per cent of entitlement volume, but does charge per megalitre for water shares transferred from the spillable water account to an allocation bank account for the Murray system. The fee for transferring water from the spillable water account back to an allocation bank account is $4.52/ML for the Murray system. See http://www.g-mwater.com.au/customer-services/carryover#1 for more information.

6. Governance

6.1 Delivery partners: roles and responsibilities

The major strategic partners in delivering water to the Yarrawonga to Tocumwal reach and Barmah-Millewa forest are presented in Table 15.

Table 15: Agencies involved in environmental water management at Barmah-Millewa forest (MDBA in prep).

Agency	Description
MDBA (Cwth)	Murray-Darling Basin Authority. Responsible for coordination at a MDB scale. Representatives on ICC and TAC.
SEWPaC	The Australian Government Department of Sustainability, Environment, Water, Population and Communities develops and implements national policy, programs and legislation to protect and conserve Australia's environment and heritage.
CEWH	The *Water Act 2007* established the Commonwealth Environmental Water Holder (CEWH) to manage the water entitlements that the Australian Government acquires to be used to protect or restore environmental assets. Representatives on EWAG and state/catchment watering groups as observers.
OEH (NSW)	OEH is responsible for water in the environment and water licensing and allocation. Incorporates functions of the Murray Wetland Working Group. OEH of the Murray Lower Darling Environmental Water Advisory Group and the TLM Environmental Watering Group. It is also the land manager of Murray Valley National Park and Murray Valley Regional Park (ex Millewa forest group) under the *National Parks and Wildlife Act 1979 (NSW)*, as well as the NSW Icon site manager and Water manager within forest boundaries
DPI (NSW)	NSW Water Manager (NSW Office of Water) has responsibility for water extraction in terms of planning and licensing under the *Water Management Act 2000 (NSW)*. Leading the NSW commitment to the Living Murray Environmental Works and Measures Program. Directs the operations of NSW State Water in accordance with Water Sharing Plans, legislation and policies. Member of the TLM Environmental Watering Group and Technical Advisory Committee (TAC).
State Water Corporation (NSW)	NSW's rural bulk water delivery corporation that also manages, operates, and maintains NSW water regulation infrastructure. Manages and operates Murray-Darling Basin Authority identified assets in accordance with the Murray-Darling Basin Agreement.

Agency	Description
Murray Catchment Management Authority (MCMA) (NSW)	The Murray CMA is a statutory authority with a responsible and accountable board reporting directly to the NSW Minister for Primary Industries . The MCMA is responsible for managing natural resource issues at the catchment scale through engagement of regional communities, development of a catchment action plan and implementation of incentive programs. MCMA chairs the Murray/Lower Darling Environmental Water Advisory Group and Community Reference Group, and is also a member of TAC.
DSE (Vic)	Victorian Department of Sustainability and Environment. Responsible for implementing TLM in Victoria, site owner for public land and manager of approvals/referrals for the state. Representatives on Barmah-Millewa Integrated Coordinating Committee (ICC) and TAC.
Parks Victoria	Parks Victoria is the land manager for Barmah National Park. Representatives on ICC and TAC.
Goulburn Broken CMA	Goulburn Broken Catchment Management Authority is the Victorian TLM icon site manager. Representatives on ICC (chair alternate years) and TAC (chair alternate years).
G-MW	Goulburn-Murray Water. Victorian constructing authority for TLM – responsible for operation and maintenance of infrastructure built through TLM Initiative. Representatives on TAC.
Yorta Yorta Nation Aboriginal Corporation	Recognised in Victoria as the Registered Aboriginal Party. Victoria will ensure co-operative management of Barmah forest with the Yorta Yorta Peoples in land and water management decision making relating to the protection, management and sustainability of their country, including cultural and environmental values.
Victorian Environmental Water Holder	Independent manager of State-based environmental water entitlements (effective July 2011).

6.2 Approvals, licenses, legal and administrative issues

6.2.1 Water shepherding and return flows

For water delivered from NSW or Victorian accounts, and for target flows below 30,000 ML/d downstream of Yarrawonga Weir, the delivery point can be specified as the Murray River at Picnic Point for diversion through the various regulators on either side of the river. The only consumptive diversions near this location are the flows along the Edward River and Gulpa Creek, which are limited by the capacity of the regulators, flows along Lower Toupna Creek to deliver water to the Bullatale Creek Irrigation Trust (commence to flow 6,000 ML/d) and diversions at the Moira pumps to supply a small private irrigation trust west of Moira Lake (commence to flow 4,000 ML/d) (MDBA 2010c). These diversions all operate at much lower river flows and they legally cannot divert water without having first ordered it from State Water.

Some of the water delivered into the Barmah-Millewa forest will return to the Murray River downstream of the Choke. Estimation of the loss and return flows is seasonally variable. Loss relationships are specified in MSM-Bigmod (Figure 8) (MDBC 2002).

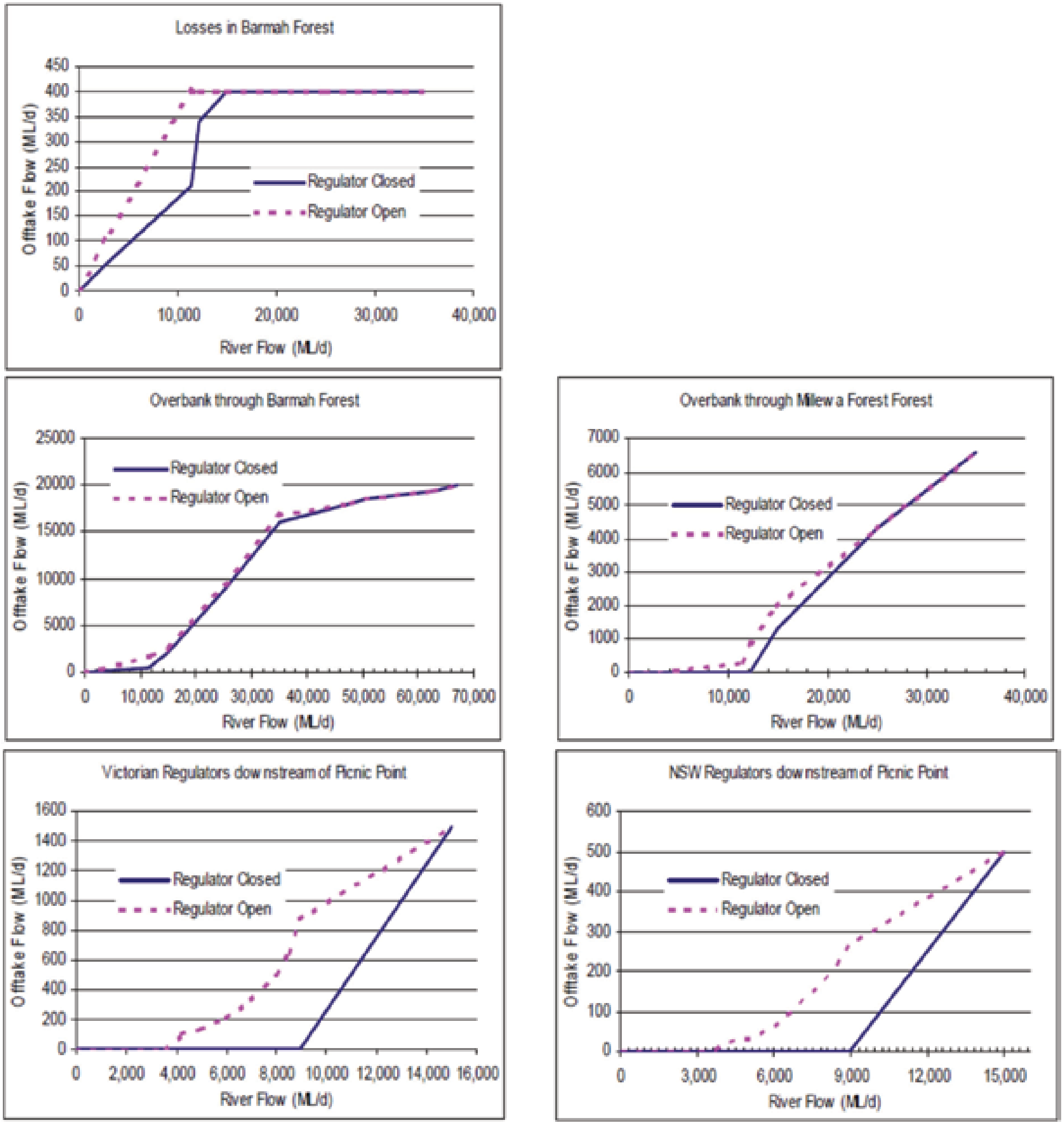

Figure 8: Loss and overbank flows through Barmah-Millewa forest in MSM-Bigmod (MDBC 2002).

The 2010 watering event provided an opportunity to estimate return flows associated with water deliveries to the forest. Due to uncertainty with the calculations this methodology will not be applied again. Similarly, the loss associated with opening the regulators every year are unknown. Loss calculations can be undertaken using the range of flow gauges along the Murray River after making an allowance for gauged diversions along Gulpa Creek and the Edward River. Flood peaks are likely to significantly attenuate through the forest, so loss calculations should be over a period that is long enough (approximately one month) to incorporate that attenuation. Loss is expected to be lower if a previous flood event has already wetted the forest prior to the watering event.

In NSW, Section 45 of the Water Sharing Plan for the NSW Murray and Lower Darling Regulated Rivers Water Sources allows water allocations to be re-credited in accordance with return flow rules established under Section 75 of the *Water Management Act 2000 (NSW)*. The process is to apply to the Minister for used water allocations to be re-credited to the licence. The return flow rules by which the application is to be assessed have not been formally established. Until such time as this policy is finalised, the process by which return flows could be granted would be for the environmental water holder to apply to the NSW Minister for Water for the relevant licence to be re-credited.

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 provided that (DSE 2009):

- There is adequate rigour in the calculation and/or measurement of return flows
- The return flows meet relevant water quality standards
- Additional loss (if any) is 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.

If allocations in the Murray River are temporarily transferred to the Victorian Minister for Environment's Flora and Fauna entitlement, then return flows to the Murray River can more readily be credited under Clause 15 of the entitlement. Specified points for diversion and return flows are listed in Schedule 4 to the entitlement; however there are no return flow locations actually specified in this schedule, only offtake points at four locations in the Barmah forest. If return flows are to be re-credited to the Flora and Fauna entitlement at other locations, then it must be by agreement with the MDBA.

If allocations in the Murray River are temporarily transferred to the Victorian Minister for Environment's environmental entitlement for the Murray River – Environmental Water Reserve, then credits for return flows can be granted under Clause 10 of this entitlement, subject to various conditions. The assessment of the return flow calculations and crediting would be undertaken by Goulburn-Murray Water. If these credits were granted, then the environmental water holder would need to discuss how the credits might subsequently be used with the Victorian Environmental Water Holder, who would be granted the credits.

6.2.2 Trading rules and system accounting

Water Trading

A map of the trading zones for the southern Murray-Darling Basin is shown in Figure 9.

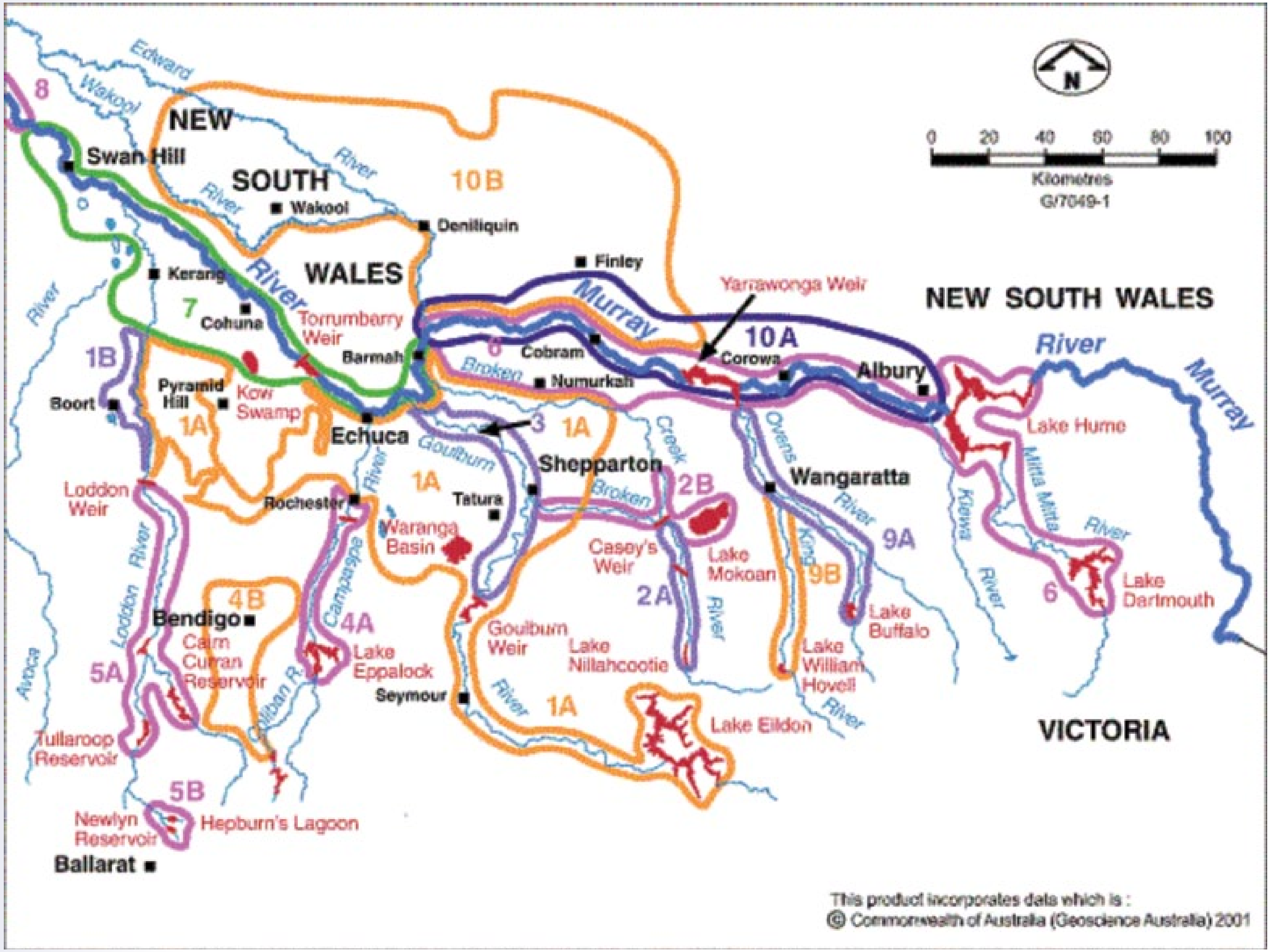

Figure 9: Trading zone boundaries (http://www.watermove.com.au).

The Barmah-Millewa forest is located in Trading Zone 10A (NSW Murray above Barmah) for water shares held in NSW and in Trading Zone 6 (Vic Murray Dartmouth to Barmah) for water shares held in Victoria. Water shares from these trading zones can be traded to all other zones in the southern connected Murray-Darling Basin, subject to the following constraints:

- Trade into areas downstream of the Barmah Choke including Victorian tributaries is limited to the volume of back trade to date.
- Trade into Murray Irrigation Limited areas (zone 10B) currently attracts a 10 per cent loss of share volume. This 10 per cent loss only applies when using the Murray Irrigation Limited channel system to deliver water and does not apply to water delivered via rivers (D.Jacobs, NOW, pers. comm. December 2010).

Water shares from all other zones in the southern connected Murray-Darling Basin can be traded to Trading Zone 10A (NSW Murray above Barmah) or 6 (Vic Murray Dartmouth to Barmah), subject to the following constraints:

- Trade from Murray Irrigation Limited areas (zone 10B) receives a 10 per cent gain in share volume.
- Permanent trade is currently limited to 4 per cent per year from irrigation districts in Victoria. Goulburn-Murray Water advises via media release 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.

In practice, these rules mean that additional water shares to provide additional environmental flows in the Murray River upstream of Barmah can be traded without restriction. If the water shares held in the Murray above Barmah are to be used downstream of the Choke, then their use will be restricted to the volume of back trade. The volume of back trade at any given time is stated at http://www.waterregister.vic.gov.au/Public/Reports/InterValley.aspx.

For more information on water trading rules, see http://www.watermove.com.au/ or the Victorian Water Register (for Victoria only).

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 managers must make any allocation trades well in advance of a targeted runoff event.

Water trading attracts water trading fees. If water trading is conducted without the use of a broker, the fees are currently less than $200. See the Victorian Water Register for Victorian fee schedules at http://www.waterregister.vic.gov.au/Public/ApplicationFees.aspx or State Water's website at http://www.statewater.com.au/Customer+Service/Water+Trading for fees in NSW.

Water storage accounting

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 carry over rules are based on the Water Sharing Plan for the New South Wales Murray and Lower Darling Regulated Rivers Water Sources 2003, which were suspended from 2006 due to on-going dry conditions, but recommenced from 1 July, 2011 with the recent improvements in resource availability.

Water storage accounting for the Victorian Murray system is annual water accounting (July to June) with some carryover. 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, water in spillable water accounts is the first to spill. Annual deduction for evaporation is 5 per cent of carried over volume. The fee for transferring water from the spillable water account back to an allocation bank account is $4.52/ML for the Murray system. See http://www.g-mwater.com.au/customer-services/carryover#1 for more info.

For more information on carryover, see http://www.g-mwater.com.au/customer-services/carryover/lbbcarryover/.

For more information about water storage accounting in other parts of the southern connected Murray-Darling Basin, refer to the environmental water delivery documents for the Murrumbidgee River, South Australia and the Victorian tributaries.

If the Hume Dam spills, then the Barmah-Millewa Environmental Water Allowance in NSW and Victoria is designated as the first account to spill prior to consumptive users (MDBC 2006).

6.3 Water use plans

The following water use plans are relevant to environmental water delivery to the Barmah-Millewa forest:

The Living Murray Environmental Water Management Plan

The Environmental Water Management Plan (EWMP) provides a framework for the delivery and management of environmental flows to achieve the ecological objectives of the Barmah-Millewa Icon Site. The plan describes management objectives and targets, water delivery arrangements and the specific watering regimes for the Barmah-Millewa icon site, as it relates to The Living Murray (TLM) program. The EWMP is used as a guide for the use of all environmental water management, including water sourced from NSW and Victorian resources, Australian Government water and donated water.

It is intended for the EWMP to be renewed on a five yearly basis. However, it has been revised more frequently in recent years to reflect improved knowledge and changing circumstances (MDBC 2006; MDBC 2007).

The Living Murray Annual Water Delivery Plans

Annual Water Delivery Plans are developed for approved watering actions at TLM icon sites. The plans describe objectives for watering and operational strategy at these sites, including specific actions associated in the event of particular flow events. Water delivery plans also recognise the difference in desired timing of flooding, distinguishing between seasonal flooding and unseasonal flooding, which are generally defined by winter to spring flooding versus summer to autumn flooding.

7. Risk assessment and mitigation strategies

7.1 Approach

Potential risks of delivering environmental water to the Barmah-Millewa system have been assessed according to the SEWPaC risk assessment framework (see Appendix 4) and are summarised in Table 16. The risk assessment provides an indication of the risks associated with the delivery of environmental water in the Barmah-Millewa system. 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 water delivery. Note that the risks outlined are the unmitigated risks, i.e. the risk from the event in the absence of adaptive management.

Risks in the Yarrawonga to Tocumwal Reach of the Murray River have not been included in this assessment because there is insufficient data available to determine existing hazards, or the flows at which they become significant.

7.2 Risks

Blackwater events

Blackwater events occur when organic debris on the floodplain is inundated. Decomposition of leaves, bark, wood and other organic matter consumes oxygen, creates low dissolved oxygen conditions and releases tannins which colour the water. Anoxia persists where there are high organic loads and high concentrations of decomposing microbes that can result in fish deaths. Blackwater conditions are more likely to occur when water temperatures are high, in summer and early autumn, and where there is poor water circulation. However, in 2010–11 blackwater was present in Barmah-Millewa forest in spring and could have been promoted by exceptionally long periods between major floods as a result of the recent drought. This may have caused the accumulation of a very high load of previously unflooded organic matter (Gigney et al. 2006, Howitt et al. 2007). As a result, careful management of environmental water delivery is required to minimise blackwater risks (see Table 16).

Pest plants and animals

Floodplain inundation supports increased fish breeding, including non-native species. Of particular concern is common carp (*Cyprinus carpio*), but flooding of Barmah-Millewa forest has also increased the breeding of goldfish (*Carassius auratus*) and oriental weatherloach (*Misgurnus anguillicaudatus*) (King et al. 2007). The benefits of the floodplain to native fish recruitment are significant, and considered to outweigh the threat posed by pest species. There is little to distinguish the flooding preferences of exotic and native species, and mitigation measures involving flow manipulation are limited. Non-flow related options should be explored (e.g. screens and traps) but are likely to be of minimal effect in overbank flow situations.

A number of aquatic pest plants, including arrowhead (*Sagittaria montevidensis*), are present in the forest and benefit from floodplain inundation (McCarthy et al. 2006). Again, there is little to distinguish the flooding preferences of native and exotic species, and flow related mitigation measures are not available. The threat may be mitigated via weed control measures within the forests.

Giant rush

Giant rush is indigenous to the forest but has increased in abundance in low lying areas as summer and autumn flooding has increased. The operation of the river at bankfull capacity to supply water demands downstream of the Choke increases the likelihood overbank flows in this period. Giant rush has invaded areas formerly occupied by moira grass and threatens this plant community.

Environmental watering options have been proposed that increase winter to spring flooding and avoid summer to autumn flooding. However, it may be desirable to prolong high flows into summer when waterbird breeding or blackwater mitigation flows are provided. These benefits should always be assessed in relation to giant rush.

River red gum encroachment on moira grass

The depletion of floods between 10,000 ML/d and 35,000 ML/d has provided opportunities for river red gum to colonise lower-lying areas that were formerly dominated by moira grass. Winter to spring floods that typically persist for less than five months promote river red gum recruitment.

Environmental watering options should be managed to avoid further establishment of river red gums within the moira grass wetlands. This is best achieved by providing long floods of five to nine months duration in the moira grass plains, which exceed river red gum tolerance. Short floods promote river red gum germination and sapling establishment, and hence should be avoided. In some circumstances it may be appropriate to forego brief watering opportunities if they are likely to promote river red gum and degrade moira grass wetlands.

Flooding of infrastructure

Releases of more than 25,000 ML/d from Hume Reservoir are limited due to the risk of flooding to private property. Environmental watering options have been developed to accommodate this limitation and will not promote flooding of private land.

Salinity

The Murray River and floodplain between Tocumwal and the Goulburn River junction loses water to the aquifer and has a low risk of discharge of saline groundwater to the ecosystem (CSIRO 2008).

Groundwater has been monitored at Barmah forest since 1984. A recent review suggests that groundwater levels are influenced by rainfall and potentially by surface water features (particularly in areas close to the Murray River) (SKM 2005).

A network of 98 bores monitors aquifer systems underlying Barmah forest on a monthly basis where possible. They are used to detect salinity annually in April by Goulburn-Murray Water. A recent independent review of the groundwater monitoring program states that the bore network and its monitoring frequency is adequate and the current threat of saline groundwater on Barmah forest is low (SKM 2005). There are no identified salinity risks associated with environmental watering options.

Acid Sulphate Soils

Exposure of acid-forming soils can acidify the water column which, when re-flooded, release toxic minerals and kills plant and animal life. The likelihood of acid sulphate soil formation in Barmah-Millewa is considered low (GHD 2010; MDBA 2010a). Therefore, this is not considered a significant risk for environmental watering options.

Rapid Drawdown

A rapid reduction in river discharge between 30,000 ML/d and 10,000 ML/d interrupts plant growth and fauna breeding and can strand fish on the floodplain. Rapid drawdown is currently a threat associated with river operations that seek to match the releases from Hume Reservoir to water demand as closely as possible. After flood events, water demand is typically low and river level operators reduce river levels as quickly as possible (by as much as 15 cm/d at Doctors Point and 30 cm/day downstream of Yarrawonga) as a consequence (MDBA 2010c).

Environmental watering options have been developed to mitigate this risk by releasing environmental water to reduce drawdown rates. However, rapid drawdown is also a risk associated with environmental water releases and may occur if a watering event is interrupted. When watering events are planned, the rate of drawdown should be considered and measures put in place to minimise the risk of rapid drawdown.

Table 16: Risk associated with water delivery in Barmah-Millewa forest.

Risk type	Description	Likelihood	Consequence	Risk level	Mitigation
Blackwater	Blackwater events have been recorded with the release of water after prolonged dry or low flow periods. This can occur from in-channel litter build-up as well as when floodwaters are returned to streams off floodplain surfaces.	Possible	Moderate	Medium	Blackwater risks may be reduced by: • providing recommended floodplain inundation regimes that avoid sustained periods without flooding • minimising floodplain inundation in warm summer months.
Pest plants and animals	Carp breeding is likely to be favoured by large flow events in the forests as is the spread of the noxious weed arrowhead.	Likely	Minor	Medium	Flow options for disruption of carp spawning can be investigated. However, any measures would need to maintain native fish spawning. Weed control measures to limit the spread and decreases the abundance of arrowhead should be explored.
Giant rush encroachment on moira grass	Increased frequency and duration of inundation of low lying plains favours giant rush over moira grass.	Likely	Moderate	Medium	Minimise summer-autumn flooding of moira grass plains.
River red gum encroachment on moira grass	Decreased frequency and duration of inundation of moira grass plains favours the establishment of river red gum.	Likely	Moderate	Medium	Minimise the occurrence of floods less than 5 months long in the winter-spring period in the moira grass plains.
Salinity	Salt water can wash from the bottom of deep pools if stratification develops and then is broken by sudden high flows.	Rare	Minor	Low	None required.
Acid sulphate soils	Conditions throughout the forests are not considered likely to contain potential acid sulphate soils.	Rare	Moderate	Low	None required.
Rapid drawdown	A rapid fall in water levels can lead to a loss of recruitment of both fish and waterbirds, as well as impacts to wetland flora.	Possible	Moderate	Medium	Design environmental releases with a suitable flood recession.
Flooding of property	Releases of more than 25,000 ML/d from Hume Reservoir can result in flooding of private property.	Unlikely	Moderate	Low	Limit regulated releases from Hume Reservoir to target <25,000 ML/d at Doctors Point.
Recreational access	Some track access can be cut during flood events. Lengthening the duration of these events with environmental water deliveries may lengthen the period for which parts of the forests cannot be accessed by recreational users.	Possible	Minor	Low	Work with other stakeholders to assess access risks in flood events and adjust watering accordingly. Community education to inform on benefits of flooding in floodplain ecosystems.

8. Environmental Water Reserves

8.1 Environmental water holdings and provisions

8.1.1 Water planning responsibilities

The Water Sharing Plan for the NSW Murray and Lower Darling Regulated Rivers Water Sources, which previously governed water management in the NSW Murray River, was suspended in November 2006 due to prolonged drought conditions. Water sharing is currently directly administered by the NSW Office of Water. Due to recent improvements in water availability, the water sharing plan recommenced from 1 July, 2011.

The adaptive environmental water and the Murray Additional Environmental Allowance under the water sharing plan is overseen by the NSW Office of Environment and Heritage (OEH). OEH prepared an annual adaptive environmental water plan for the Murray Valley, which was available in draft form at the time of preparing this document (DECCW 2010). 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 Valleyand Lower Darling. This includes representatives from the Murray Catchment Management Authority, NOW, DPI Fisheries and State Water.

The Northern Region Sustainable Water Strategy (NRSWS) provides the strategic direction for water management across Northern Victoria (DSE 2009). Responsibilities for planning and delivery of water specified in Victorian environmental entitlements in the Murray River upstream of the forest are managed by the Department of Sustainability and Environment in conjunction with the North East Catchment Management Authority.

The Barmah-Millewa forest has its own Environmental Water Allowance (EWA) of 100,000 ML/yr which is contributed equally from Victoria and NSW, based on Victorian high reliability water share allocations. In addition, the EWA includes a lower security allocation of 50,000 ML/yr (again to be contributed equally from Victoria and NSW) which is allocated when natural inflows to Hume Reservoir exceed the specified triggers. Collectively these are termed the Barmah-Millewa Environmental Water Allowance. Under the current Barmah-Millewa forest watering operating rules, each State's share of the environmental water allowance can be borrowed by that State when allocations would be below the State's target allocations. The EWA has special conditions for borrowing in the fifth consecutive year of drought.

Forest regulators in NSW are controlled by OEH under the direction of the MDBA and operated by NSW National Parks and Wildlife Service. Forest regulators in Victoria are controlled by Goulburn-Murray Water under the direction of the MDBA and operated by the Department of Sustainability and Environment.

8.1.2 Environmental Water Provisions

Minimum flows 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 allowance is listed in Table 18. Similarly the environmental entitlements for the Victorian Minister for Environment do not specify minimum channel flows in the Murray River because they are covered by MDBA operating rules.

During the irrigation season, flows are generally running above natural streamflows because of irrigation deliveries from Hume Dam to areas downstream. During the non-irrigation season, minimum flows in the Murray River are provided from the Ovens and Kiewa River.

The filling of Hume Dam typically occurs from the end of the irrigation season in mid-May to sometime in late winter or spring, depending on seasonal conditions and irrigation demand. During the filling phase, minimum releases are maintained for as long as possible. The minimum release from the storage is 600 ML/d and this is increased if necessary to ensure that a minimum flow of 1,200 ML/d is maintained at Doctor's Point, immediately downstream of the junction with the Kiewa River, a few kilometres below Hume Dam. The intent is to provide sufficient flow for riparian and instream environmental needs during winter (MDBA 2010a).

In the very dry winter of 2007, the release from Hume Dam was reduced to 400 ML/d as part of the special circumstances allowed under the Drought Contingency Planning. The 400 ML/d relates to the minimum allowable opening of an irrigation valve on the dam outlet (MDBA 2010c).

Other minimum flows downstream of Yarrawonga Weir are maintained for operational purposes. A minimum of 1,800 ML/d is maintained "to provide minimum flows for riparian and water quality requirements" (MDBA 2010a). When releases 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 that flows are generally maintained above these values during the irrigation season.

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 17. Licences have been identified separately upstream and downstream of the Barmah Choke, as this can sometimes be a restriction on trade. The volume available upstream of the Choke is up to approximately 194,000 ML, whilst licences below the Choke can provide up to an additional 329,000 ML if traded to upstream of the Choke. Volumes of Commonwealth environmental water are constantly being updated. For the latest figures see www.environment.gov.au/ewater.

Figures in tables 17 and 18 are based on allocation information from MSM-Bigmod modelling of the Murray River system with The Living Murray deiiveries in place (run #22061).

Table 17: Commonwealth environmental water holdings (as at October 2010).

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

* The Australian Government holds 70.0 ML of regulated river entitlement on the Ovens System; however this water cannot be traded outside of the Ovens Basin.

** The Australian Government holds 20,820 ML of supplementary water shares on the Murrumbidgee System; however this water cannot be traded outside of the Murrumbidgee Basin.

*** The Australian Government holds 20.0 ML of high reliability water share and 4.2 ML of low reliability water share on the Broken System; however this water cannot be traded outside of the Broken Basin.

Environmental water currently held in the Murray River upstream of the Choke by other agencies is listed in Table 18. Only volumes upstream of the Choke have been listed, as these other water shares are generally tied to use at specific locations which preclude trading to upstream of the Choke from elsewhere. Where trade from elsewhere is possible for the watering of assets upstream of the Choke, it is difficult to predict under what circumstances that trade would occur. This table indicates that up to 150,000 ML/yr can be allocated specifically to the Barmah-Millewa forest in any given year, plus up to around a further 600,000 ML/yr from other environmental entitlements in a wet year.

Table 18: Environmental water currently held by other agencies in Murray River upstream 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 GL high security and ~15 GL general security). 2,027 unit shares high security (~2 GL).	The plan was suspended in 2006 due to drought but recommenced 1 July 2011. (can be carried over and accumulate over a number of years)
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 GL).	The plan was suspended in 2006 due to drought but recommenced 1 July 2011. (can be carried over and accumulate over a number of years)
Water Sharing Plan for the NSW Murray and Lower Darling Regulated Rivers Water Sources – **Barmah-Millewa Environmental Water Allowance**	50,000 ML when NSW high security allocation is ≥97 per cent plus 25,000 ML when Victorian low reliability water share allocation is >30 per cent.	The NSW WSP was suspended in 2006 due to drought but recommenced 1 July 2011. Account can be accrued over several years. The maximum credit that can be held against the allowance is 350,000 ML.
Victorian Minister for Environment (in Trust for Snowy Recovery) – Barmah-Millewa forest Environmental Water Allocation (Vic)	50,000 ML allocated based on Victorian high reliability water share allocations plus 25,000 ML when Victorian low reliability water share allocation is >30 per cent.	Account can be accrued over several years.
Victorian Minister for Environment (in Trust for Snowy Recovery) – **Snowy Environmental Reserve**	29,794 ML high reliability water share.	Total available upstream and downstream of the Choke.
Murray River – Flora and Fauna Conversion Further Amending Order (2009)	40,298 ML low reliability water share. 3,630 ML high reliability water share.	
The Living Murray – **NSW Murray system**	1,887 high security. 134,387 general security. 350,000 ML supplementary. 12,965 ML unregulated.	Total available upstream and downstream of the Choke.

8.2 Seasonal allocations

State Water calculates available water determinations every month, which are then confirmed and issued by Office of Water. The latest announcements are listed at http://www.water.nsw.gov.au/Water-Management/Water-availability/Available-water-determinations/default.aspx, whilst a register of historical announcements is listed at http://www.wix.nsw.gov.au/wma/DeterminationSearch.jsp?selectedRegister=Determination, however the historical announcements website is not always kept up to date.

Victorian allocations are announced by Goulburn-Murray Water every month and are published at http://www.g-mwater.com.au/news/allocation-announcements/current.asp.

Long-term seasonal allocations are shown for October and April as indicative of spring and autumn in Figure 10 and Figure 11. This information is sourced from MSM-Bigmod post-TLM run (#22061). These figures indicate that the full high and low security volume is provided by October in just under 50 per cent of years. Allocation data for the conveyance licence was not available from the CSIRO, but has reliability between the high and low security licences.

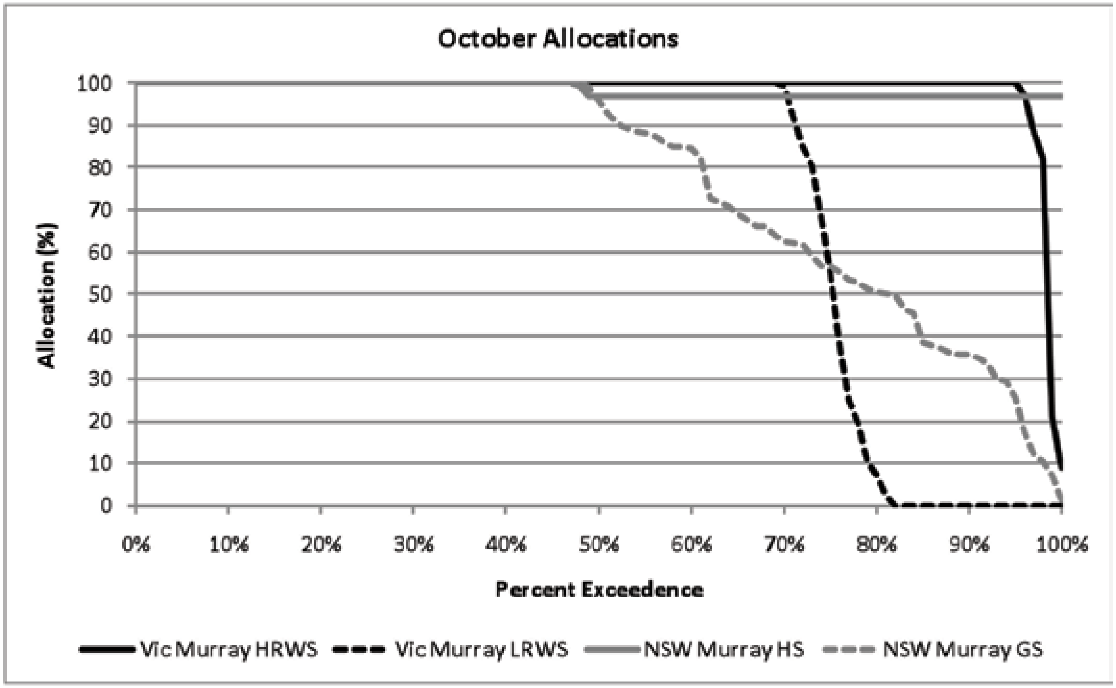

Figure 10: October seasonal allocations for the Murray system.

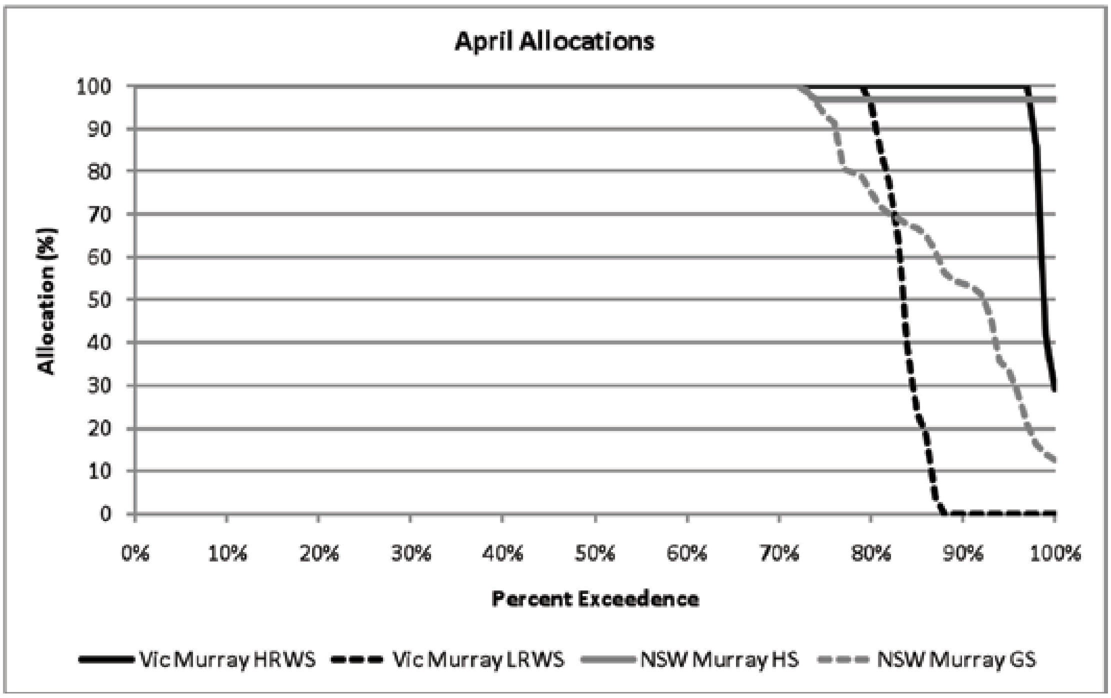

Figure 11: April seasonal allocations for the Murray system.

The allocation expected to be available (in terms of announced allocation) to the environment under different climate conditions is summarised in Table 19. The volume of water expected to be available to the environment under different climate conditions is summarised in Table 20. The calculation of the volume of water expected to be available to the environment under each climate condition is based on the volume and type of entitlements held and the expected announced allocation for each climate condition (from modelling).

This table shows, for example, that the Australian Government could expect to have in the order of 5,000 ML of water available above the Choke in spring in a very dry year and 193,000 ML of water available above the Choke in a wet year (based on October 2010 water holdings). If water is traded from other locations within the connected southern Murray-Darling Basin, then up to 44,000 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 water holdings), subject to any trading constraints outlined in Section 5.3.1.

Table 19: Likely announced allocation for Commonwealth environmental water holdings under different climate scenarios.

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	100v
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 20: Likely volume available to the environment from the Commonwealth environmental water holdings (as at October 2010).

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

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
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

In recent years, the Office of Water has provided regular "critical water planning communiqués" for the New South Wales Murray during periods of exceptional circumstances. See http://www.water.nsw.gov.au/Water-Management/Water-availability/Critical-water-planning/default.aspx for an example of these communiqués, which 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 for the New South Wales Murray, the Office of Water provides allocation announcements via media releases on the 1st and 15th of each month, along with key information concerning water management and availability. See http://www.water.nsw.gov.au/Water-management/Water-availability/Water-allocations/Available-water-determinations/default.aspx for an example of these media releases.

A description of likely water availability for the Victorian Murray System is provided by Goulburn-Murray Water when allocation 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: http://g-mwater.com.au/news/allocation-announcements/current.asp. Historical announcements and forecasts can be sourced from: 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 October and February allocations for the following season. The seasonal allocation outlooks are published on Goulburn-Murray Water's website (see Media Releases). Note that in years with high water availability, only the seasonal allocation outlook may be prepared (i.e. water availability forecasts may not be provided with allocation announcements).

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 Barmah-Millewa forest. Four monitoring programs that have been established under the Living Murray Outcomes Evaluation Framework are:

- **Murray River system-scale monitoring** which measures changes in ecology across the Murray River system in relation to fish, waterbirds and vegetation. Conducted annually.
- **Icon Site condition monitoring** to assess condition in relation to Icon Site objectives (outlined in Table 21).
- **Intervention monitoring** 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.
- **Operational monitoring** aims to determine if environmental watering has been undertaken as planned and assesses risks (e.g. water quality and salinity changes) by measuring the volume (including return flows, timing and quality) for use in accounting and reporting.

Table 21: Icon Site condition monitoring components for Barmah-Millewa forest.

Component	Monitoring Approach
Vegetation – overstorey	Remotely sensed vegetation mapping
	TLM stand condition assessment
	TLM tree condition assessment
Vegetation – understorey	Understorey vegetation mapping (spatial character)
	Understorey condition monitoring
Waterbirds	Waterbird condition monitoring ground surveys
	Waterbird assessment: aerial survey
	Woodland birds
Fish	SRA compatible assessment of the fish community
	Fish spawning and recruitment
	Spawning of large-bodied fish
	Crayfish populations
Amphibians and Reptiles	Frog sampling
	Turtle survey

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

There are various measuring points for environmental watering relevant to the Barmah-Millewa forest, as listed in Table 22. This includes a combination of streamflow monitoring along the Murray River and from the main tributaries downstream of Lake Hume Dam, and water level monitoring at various points within the Barmah-Millewa forest. Real-time data is available at http://www.mdba.gov.au/water/live-river-data/yarrawonga-to-euston for main Murray River sites or in more detail at http://waterinfo.nsw.gov.au/. Historical data and maps of site locations are also available at http://www.dse.vic.gov.au/waterdata/.

Table 22: Flow monitoring in the Murray River near Barmah-Millewa forest.

Site number	Site name	Relevance to this plan
409016	Murray River at Heywoods	Flows from Hume Dam
402205	Kiewa River at Bandiana	Flows from Kiewa River u/s Murray River
409017	Murray River at Doctors Point	Flows in Murray River d/s Kiewa River
403241	Ovens River at Peechelba East	Flows in Ovens River u/s Murray River
409025	Murray River d/s Yarrawonga	Flows d/s Yarrawonga Weir
409391	Gulf Creek at Gulf Track Regulator	Water level measurement in Barmah forest
409226	Toupna Creek at Murphys Crossing	Water level measurement in Millewa forest
409227	Mary Ada Creek at Mary Ada Crossing	Water level measurement in Millewa forest
409395	Smiths Creek at Gowers Track	Water level measurement in Barmah forest
409393	Gulf Creek at Long Plain Track – Keys Point	Flow measurement in Barmah forest
409394	Snag Creek at Gowers Track	Water level measurement in Barmah forest
409396	Budgee Creek at Sand Ridge Track	Water level measurement in Barmah forest
409397	Little Budgee Creek at Forcing Yard Track	Water level measurement in Barmah forest
409229	Wild Dog Creek at Douglas Swamp	Water level measurement in Millewa forest
409230	Reed Beds Swamp at Gulpa Creek	Water level measurement in Millewa forest
409006	Murray River at Picnic Point	Flows through the Barmah Choke d/s Gulpa Creek
409398	Budgee Creek at u/s Barmah Lake	Water level measurement in Barmah forest
409232	Moira Creek at Moira Lake	Water level measurement in Millewa forest
404210	Broken Creek at Rices Weir	Flows from Broken Creek
409215	Murray River at Barmah	Flows d/s of Barmah-Millewa forest

9.2 Operational water delivery monitoring

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 of future watering events. Key questions to be addressed include the following:

- How did actual water use compare with estimated water use? Can future estimates of water use be improved?
- How well did delivery procedures work? Can releases and regulator operation be improved to increase efficiency, increase effectiveness and reduce undesirable impacts?
- Were there constraints on delivery that affected the watering event?
- Were unmanaged components of the system (e.g. catchment inflows and unregulated flows in the Kiewa and Ovens rivers) accommodated?

Two approaches are currently used to determine water use in environmental watering events. In recent drought years, when events have used very small water volumes and regulation has been very tight, water use has been calculated by measuring flow at individual forest regulators. When larger volumes have been applied, bulk calculations have been made by Murray River Operations by comparing flows past Tocumwal (into the forest) with flows past Barmah and Deniliquin (out of the forest).

An extension to the hydrodynamic model for Barmah-Millewa forest could provide additional estimates of use for a variety of water delivery scenarios. This would be particularly useful for the proposed routine diversion of winter to spring flows through the forest.

It is important to acknowledge the complexity of water management in the forest. There are large numbers of watercourses and regulators whose settings affect water use and are dynamically adjusted through the course of watering events. Modelling of individual watering events to estimate water use would be time consuming and expensive, and therefore may not suitable for routine evaluation.

Table 23: Monitoring requirements for environmental water delivery and use.

Component	Monitoring Approach	Source of Information
Total volume of water delivered in watering event	Releases from Hume Dam. Flow downstream of Yarrawonga Weir.	Murray River Operations.
Start date and end date	Murray River Operations records.	Murray River Operations.
Structure operations	Times and operation of storages, forest regulators and other flow control structures during watering events.	Murray River Operations (oversight). Parks Victoria (Barmah regulators). NSW NPWS (Millewa regulators). Murray Irrigation Limited (Irrigation regulators in NSW).
Environmental water use	Low flows: measure discharge at forest regulators to complement flow data loggers.	River Murray Operations (regulator flow measurement and data loggers).
	High flows: compare discharge at Tocumwal with Barmah and Deniliquin.	Murray River Operations.
	Proposed approach: Develop water use estimates for a range of standard flow scenarios using the hydrodynamic model.	Further work is required.

9.3 Key parameters for monitoring and evaluating ecosystem response

Recommended monitoring to inform management of environmental water in Yarrawonga to Tocumwal and Barmah-Millewa and inform on the success of the program is summarised in Table 25.

Table 24: Monitoring plan for environmental water use.

Ecological objectives	Hypotheses	Water scenarios	Indicator(s)	Monitoring sites	Frequency	Linkages and responsibility
Manage the inundation of organic debris to reduce summer blackwater risks.	Restoring an adequate floodplain inundation regime will prevent excess accumulation of litter and reduce blackwater events.	Dry, Median, Wet	Dissolved oxygen (DO). Dissolved organic carbon	Effluent streams and downstream waters: Murray and Edward Rivers.	Mmonthly during inundation.	DO measured by NSW Office of Water algal monitoring program and Murray River System Scale monitoring.
Manage the inundation of organic debris to export organic matter to Murray River.	Inundation of floodplain surfaces will promote productivity in receiving waters.	Dry, Median, Wet	Phytoplankton, macro invertebrates, fish abundance.	Effluent streams and downstream waters: Murray and Edward Rivers.	To coincide with spring pulses.	TLM icon site monitoring includes fish abundance. SRA includes measures related to productivity. NSW Office of Water also manages the algal monitoring program that provides counts of blue-green algae. Murray River System Scale monitoring includes measures related to productivity.
Maintain the extent and health of key vegetation communities – giant rush and moira grass.	Proposed watering regime will maintain extent and improve condition of giant rush and moira grass communities and prevent encroachment of river red gum and giant rush into moira grass plains.	Extreme dry, Dry, Median, Wet	Vegetation extent and community composition.	Boals Deadwoods, Top Island, Little Rushy Swamp, Top Lake, Steamer Plain, Wathours Lagoon, Reed Beds Swamp, Black Gate Lagoon, Duck Lagoon, and Algaboia Plain.	Seasonally	TLM icon site condition monitoring includes extent and composition of understorey vegetation.
Maintain the extent and health of key vegetation communities – river red gum forests and woodlands.	Regular (2 to 5 year frequency) inundation of river red gum forests will maintain extent and maintain / improve condition.	Extreme dry, Dry, Median, Wet	Extent and canopy condition of floodplain forests.	Barmah and Millewa forests.	Annually.	TLM icon site condition monitoring includes stand condition and vegetation extent at icon sites including Barmah-Millewa.
Maintain native fish populations by stimulating breeding and providing connectivity between floodplain, wetland and river habitats.	Spring inundation of floodplain habitats will stimulate fish spawning and recruitment.	Dry, Median, Wet	Fish spawning and recruitment.	Range of different habitats within the forests: streams (regulated and unregulated), wetlands and floodplain.	Event driven	TLM icon site condition monitoring includes fish monitoring at icon sites including Barmah-Millewa.
Support waterbird breeding by provision of feeding and nesting habitat.	Inundation of wetlands and floodplains for 3 to 4 months to instigate successful waterbird breeding.	Dry, Median, Wet	Abundance, nest counts, fledgling success.	Boals Deadwoods, Steamer Plain, Reed Beds Swamp, Moira Lake, Barmah Lake, Duck Lagoon, Pig Hole, St Helens, Goose Swamp and Bunyip Hole.	Event driven	Both ground and aerial surveys are incorporated into TLM icon site condition monitoring.
Provide habitat for aquatic fauna such as frogs, yabbies and turtles.	Proposed water regime will provide habitat for aquatic fauna.	Dry, Median, Wet	Frog, turtle and yabby surveys.	Range of different habitats within the forests: streams (regulated and unregulated), wetlands and floodplain.	Event driven	TLM icon sitecondition monitoring includes frog and turtle monitoring at icon sites including Barmah-Millewa and yabby monitoring is proposed (MDBA 2010b).

10. Opportunities

Work is ongoing into the operation of the Barmah Choke to improve flexibility in delivering water to downstream users. Environmental water managers should keep abreast of any opportunities for environmental watering which may arise from this work.

The use of Millewa forest regulators to deliver water to the Edward-Wakool system is considered feasible when undertaken in conjunction with a Barmah-Millewa forest watering. The ability to use these regulators for the primary purpose of delivering water through to the Edward River is not well known and may provide opportunities to reduce the Murray River volumes needed to increase flows in the Edward River. The potential impact of such an action on the Millewa forest would need to be investigated.

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Appendix 1: Significant flora and fauna

Significant species in the Barmah-Millewa system (MDBA 2010a).

Common Name	Scientific Name	VIC	NSW	C'wlth
FAUNA				
Australasian bittern	*Botaurus poiciloptilus*	L, e	v	E
Australian painted snipe	*Rostratula australis*		e	V, M
Azure kingfisher	*Alcedo azurea*	n		
Barking owl	*Ninox connivens*	L, e	v	
Black-chinned honeyeater	*Melithreptus gularis*	n	v	
Blue-billed duck	*Oxyura australis*	L, e	v	
Brush-tailed phascogale	*Phascogale topoatafa*	L, v	v	
Brolga	*Grus rubicunda*	L, v	v	
Brown toadlet	*Pseudophryne bibronii*	E		
Brown treecreeper	*Climacteris picumnus*	n	v	
Bush stone-curlew	*Burhinus grallarius*	e	e	
Cattle egret	*Ardea ibis*			M
Caspian tern	*Hydroprogne caspia*			M
Carpet python	*Morelia spilota metcalfei*	L, e		
Murray-Darling rainbowfish	*Melanotaenia fluviatilis*	L, dd		
Diamond dove	*Geopelia cuneata*	L, n		
Diamond firetail	*Stagonopleura guttata*	L, v	v	
Eastern bearded dragon	*Pogona barbata*	dd		
Eastern long-eared bat	*Nyctophilus timoriensis (South-eastern form.*		v	V
Flathead galaxias	*Galaxias rostratus*		v	
Freshwater catfish	*Tandanus tandanus*	L, e	ep	
Freckled duck	*Stictonetta naevosa*	e	v	
Fork-tailed swift	*Apus pacificus*			M
Gilbert's whistler	*Pachycephala inornata*		v	

Common Name	Scientific Name			
		VIC	NSW	C'wlth
Glossy ibis	*Plegadis falcinellus*	n		M
Golden perch	*Macquaria ambigua*	v		
Greenshank	*Tringa nebularia*			M
Great egret	*Ardea modesta*	L, v		M
Grey-crowned babbler	*Pomatostomus temporalis*	L, e	v	
Hardhead	*Aythya australis*	V		
Hooded robin	*Melanodryas cucullata*	L, n	v	
Intermediate egret	*Ardea intermedia*	L, c		
Large-footed myotis	*Myotis macropus*		v	
Latham's snipe	*Gallinago hardwickii*	n		M
Lewin's rail	*Rallus pectoralis*	L, v		
Little bittern	*Ixobrychus minutus*	L, e		
Little egret	*Egretta garzetta*	L, e		
Macquarie perch	*Macquaria australasica*	L, e	v	E
Marsh sandpiper	*Tringa stagnatilis*			M
Masked owl	*Tyto novaehollandiae*	L, e	v	
Mueller daisy	*Brachyscome muelleroides*	L	v	V
Murray cod	*Maccullochella peelii*	L, e	e	V
Murray hardyhead	*Craterocephalus fluviatilis*	L, e	e	V
Musk duck	*Biziura lobata*	v		
Nankeen night heron	*Nycticorax caledonicus*	n		
Olive perchlet	*Ambassis agassizi*	ex	ep	
Painted honeyeater	*Grantiella picta*	L, v	v	
Pied cormorant	*Phalacrocorax varius*	n		
Plains wanderer	*Pedionomus torquatus*		e	V
Purple-spotted gudgeon	*Mogurnda adspersa*	ex	ep	
Purple-crowned lorikeet	*Glossopsitta porphyrocephala*		v	

Common Name	Scientific Name	VIC	NSW	C'wlth
Red-necked stint	*Calidris ruficollis*			M
Regent honeyeater	*Xanthomyza phrygia*	L, cr	e	E, M
Royal spoonbill	*Platalea regia*	v		
Sharp tailed sandpiper	*Calidris acuminata*			M
Silver perch	*Bidyanus bidyanus*	L, c	v	
Southern bell frog, growling grass frog	*Litoria raniformis*		e	V
Squirrel glider	*Petaurus norfolcensis*	L, e	v	
Square-tailed kite	*Lophoictinia isura*	e	v	R
Striped legless lizard	*Delma impar*			V
Swift parrot	*Lathamus discolor*		e	E
Superb parrot	*Polytelis swainsonii*	L, e	v	V
Tree goanna	*Varanus varius*	v		
Trout cod	*Maccullochella macquariensis*	L, cr	e	E
Turquoise parrot	*Neophema pulchella*		v	
Whiskered tern	*Chlidonias hybridus*	n		
White-bellied sea-eagle	*Haliaeetus leucogaster*	L, v		M
White-throated needletail	*Hirundapus caudacutus*			M
Annual bitter-cress	*Cardamine paucijuga s.s.*	e		v
Austral pillwort	*Pilularia novae-hollandiae*		e	
Austral trefoil	*Lotus australis*	k		
Bear's-ear	*Cymbonotus lawsonianus*	r		
Blue burr-daisy	*Calotis cuneifolia*			
Bluish raspwort	*Haloragis glauca f. glauca*			
Buloke mistletoe	*Amyema linophylla subsp. orientale*	v		
Button rush	*Lipocarpha microcephala*	v		
Common joyweed	*Alternanthera nodiflora*	k		
Cotton sneezeweed	*Centipeda nidiformis*	r		

Common Name	Scientific Name			
		VIC	NSW	C'wlth
Dark roly-poly	*Sclerolaena muricata var. semiglabra*	k		
Downs nutgrass	*Cyperus bifax*	v		
Dwarf bitter-cress	*Rorippa eustylis*	r		
Dwarf brooklime	*Gratiola pumilo*	r		
Fat spectacles	*Menkea crassa*	L, e		
Hypsela	*Hypsela tridens*	k		
Lax flat-sedge	*Cyperus flaccidus*	v		
Mountain swainson-pea	*Swainsona recta*	L, e	E	E
Mueller daisy	*Brachyscome muelleroides*	L, e	V	V
Native peppercress	*Lepidium pseudohyssopifolium*	k		
Reader's daisy	*Brachyscome readeri*	r		
Ridged water-milfoil	*Myriophyllum porcatum*	L, v		V
River swamp wallaby grass	*Amphibromus fluitans*		v	V
Slender bitter-cress	*Cardamine tenuifolia*	k		
Slender darling-pea, slender swainson, murray swainson-pea	*Swainsona murrayana*		v	V
Slender love-grass	*Eragrostis exigua*	e		
Slender sunray	*Rhodanthe stricta*	L, e		
Slender tick-trefoil	*Desmodium varians*	k		
Small scurf-pea	*Cullen parvum*	L, e	e	
Smooth groundsel	*Senecio glabrescens*	r		
Smooth minuria	*Minuria integerrima*	r		
Spiny-fruit saltbush	*Atriplex spinibractea*	e		
Squat picris	*Picris squarrosa*	r		
Summer fringe-sedge	*Fimbristylis aestivalis*	k		
Tricolour diuris	*Diuris sheaffiana*		v	
Twiggy sida	*Sida intricata*	v		
Umbrella wattle	*Acacia oswaldii*	v		

Common Name	Scientific Name	VIC	NSW	C'wlth
Violet swainson-pea	*Swainsona adenophylla*	e	e	
Winged peppercress	*Lepidium monoplocoides*	L, e	e	E
Yelka	*Cyperus victoriensis*	k		
Yellow-tongue daisy	*Brachyscome chrysoglossa*	L, v		

Conservation status is provided as follows:

VIC: Status in Victoria
L = species listed as threatened under the *Flora and Fauna Guarantee Act 1988 (Vic).*
cr = critically endangered (DSE 2007)
e = endangered in Victoria (DSE 2007)
v = vulnerable in Victoria (DSE 2007)
r = rare in Victoria (DSE 2007)
n = near threatened in Victoria (DSE 2007)
k = poorly known in Victoria (DSE 2005)

NSW: Status in NSW, as listed under the *Threatened Species Conservation Act 1995 (NSW).*
e = endangered
v = vulnerable
ep = endangered population

C'wlth: National conservation status, as listed under the E*nvironment Protection and Biodiversity Conservation Act 1999 (Commonwealth).*
CE = critically endangered
E = endangered
V = vulnerable
M = migratory

Appendix 2: Streamflows for key flow sources

Streamflows (ML/d) for the Murray River d/s 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

Streamflows (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	361	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

Streamflows (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

Streamflows (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

Appendix 3: 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 4: Risk assessment framework

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

	Environmental	People	Property	Operational
Critical	Irreversible damage to the environmental values of an aquatic ecosystem and/or connected waters/ other parts of the environment; localised species extinction; permanent loss of water supplies.	Death, life threatening injuries or severe trauma. Serious injury or isolated instances of trauma causing hospitalisation or multiple medical treatment cases. Sustained and significant public inconvenience.	Severe or major damage to private property. Significant damage to a number of private properties. Critical or major damage to public infrastructure.	Predicted water loss will prevent the achievement of planned outcomes of the watering event.
Major	Long-term damage to environmental values and/or connected waters/other parts of the environment; significant impacts on listed species; significant impacts on water supplies.	Minor injury/trauma or First Aid Treatment Case. Injuries/instances of trauma or ailments not requiring treatment. Sustained public inconvenience.	Isolated but significant economic and/or social impact. Damage to private property. Some damage to public infrastructure.	Predicted waterloss will significantly detract from the planned outcomes of the watering event.
Moderate	Short-term damage to environmental values and/or connected waters/other parts of the environment; short-term impacts on species.	Short term public inconvenience. No injuries.	Minor economic and/or social impact contained to small number of individuals.	Predicted transmission loss will moderately detract from the planned outcomes of the watering event.
Minor	Localised short-term damage to environmental values and/or connected waters/other parts of the environment; temporary loss of water supplies.	Minor public inconvenience. No injuries.	No economic impacts. Minor public inconvenience.	A small amount of water will be lost and this will have a small impact on the environmental outcomes.
Insignificant	Negligible impact on environmental values and/or connected waters/other parts of the environment; no detectable impacts on species.	No public inconvenience. No injuries.	No impacts on private property. No infrastructure damage.	Water loss will be minimal and will not affect the planned outcomes of the watering event.

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


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