QON 12 & 13 - Attachment C

Australian Government
Commonwealth Environmental Water

ENVIRONMENTAL WATER DELIVERY

River Murray—Coorong, Lower Lakes and main channel below Lock 1

MAY 2012 V1.1

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Mouth of the Murray River, Coorong National Park
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Pelicans at Long Point, Coorong National Park
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Australian Water Environments, Ecological Associates and GHD Pty Ltd. (2011). *Environmental water delivery: River Murray—Coorong, Lower Lakes and main channel below Lock 1*. Prepared for Commonwealth Environmental Water, Department of Sustainability, Environment, Water, Population and Communities.

ISBN: 978-1-921733-37-6

SEWPaC acknowledges the following individuals and organisations that have been consulted in the preparation of this document:

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Adrienne Frears (DFW)
Theresa Heneker (DFW)
Tony Herbert (DFW)
Heather Hill (DFW)
Rebecca Lester (Private consultant to DENR)
Tracey Steggles (DFW)
Lisa Stribley (DFW)
Rebecca Turner (DFW)
Jan Whittle (DFW)
Karl Hillyard (SA MDB NRM Board)
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Murray-Darling Basin Authority

Published by Commonwealth Environmental Water for the Australian Government.

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River Murray—Coorong, Lower Lakes and main channel below Lock 1

JANUARY 2012 V1.0

Environmental water delivery: River Murray – Coorong, Lower Lakes and main channel below Lock 1

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

- 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 has been prepared to provide information on the environmental assets and potential environmental water use in the River Murray system below Lock 1. As the first version of the document, it is intended to provide a starting point for discussions on environmental water use. As such, suggestions and feedback on the document are encouraged and will be used to inform planning for environmental water use and future iterations of the document.

The River Murray system below Lock 1 supports significant ecological values as well as internationally recognised wetland systems. Potential water use options for the system include providing flows to establish a variable lake level regime for Lakes Alexandrina and Albert to support riparian and floodplain vegetation; providing flows to improve connectivity between the Lower Lakes and the Coorong for the migration of fish species; and providing barrage flows to maintain water quality in the Lower Lakes suitable for salt-sensitive flora and fauna species.

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 South Australian Department of Environment and Natural Resources, South Australian Department for Water, SA Water 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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List of acronyms

ADF	Additional Dilution Flows
AHD	Australian Height Datum
ANZECC	Australian and New Zealand Environment Conservation Council
ARI	Annual Return Interval
ASS	Acid Sulfate Soils
AWD	Available Water Determination
BDBSA	Biological Data Base of South Australia
CAMBA	China–Australia Migratory Bird Agreement
CEWH	Commonwealth Environmental Water Holder
CLLMM	Coorong, Lower Lakes and Murray Mouth
CMA	Catchment Management Authority
COAG	Council of Australian Governments
DFW	South Australian Department for Water
DENR	South Australian Department of Environment and Natural Resources
EC	Electrical conductivity units
EMLR	Eastern Mt Lofty Ranges
EPBC Act	Environment Protection and Biodiversity Conservation Act 1999 (Commonwealth)
FSL	Full Supply Level
g/L	Grams per litre
GL/year	Gigalitres per year
IUCN	International Union for Conservation of Nature
JAMBA	Japan–Australia Migratory Bird Agreement
mAHD	metres Australian height datum
MDB	Murray-Darling Basin
MDBA	Murray-Darling Basin Authority
ML/day	Megalitres per day
$\mu S\ cm^{-1}$	microSiemens per centimetre
MM	Murray Mouth
Murray CMA	Murray Catchment Management Authority
RoKAMBA	Republic of Korea-Australia Migratory Bird Agreement
SA MDB NRM Board	South Australian Murray-Darling Basin Natural Resources Management Board
SARDI	South Australian Research and Development Institute
SEWPaC	Australian Government Department of Sustainability, Environment, Water, Population and Communities
TLM	The Living Murray program
USED	Upper Southeast Drainage scheme
WAP	Water Allocation Plan

PART 1:
Management Aims

1. Overview

1.1 Scope and purpose of this document

Information provided 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 the application of large volumes of environmental water.

To maximise the system's benefit, three scales of watering objectives have been 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.

Information provided focuses on the environmental watering objectives and water use strategy for the River Murray including the Coorong, Lower Lakes and main channel below Lock 1.

As part of this project, assets and potential watering options have been identified for regions across the Murray-Darling 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 management arrangements necessary to deliver water to meet ecological objectives for individual assets.
2. Water use options have been developed for each asset to meet watering objectives under a range of volume scenarios. Use of environmental water will aim to maximise environmental outcomes at multiple assets, where possible. Water use options will provide an 'event ready' basis for the use of environmental water. Options are expected to be integrated into a five-year water delivery program.

3. Processes and mechanisms required to operationalise environmental water delivery have been documented and include:
   - delivery arrangements and operating procedures
   - water delivery accounting methods (in consultation with operating authorities) 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.

1.2 Catchment and river system overview

The Murray-Darling Basin has an area of 1,042,730 square kilometres and includes parts of Queensland, New South Wales, Victoria, South Australia and the Australian Capital Territory (Figure 1-1). The headwaters of the Murray and Darling rivers and most of their tributaries rise in the Great Dividing Range. Most of the run-off comes from these higher rainfall areas of the Basin with very little entering the River Murray from run-off within the Murray region.

The natural environment of the Basin includes vast floodplains at the heart of a system of over 30,000 wetlands. These wetlands and floodplains support biodiversity of national and international significance. The Basin has one World Heritage site (the Willandra Lakes Region), 16 wetlands listed under the Convention on Wetlands of International Importance (the Ramsar Convention), and in excess of 200 wetlands listed in the Directory of Important Wetlands of Australia (CSIRO 2008). The Coorong and Lower Lakes area which forms part of this water delivery document is one of the Ramsar Convention wetlands within the Basin.

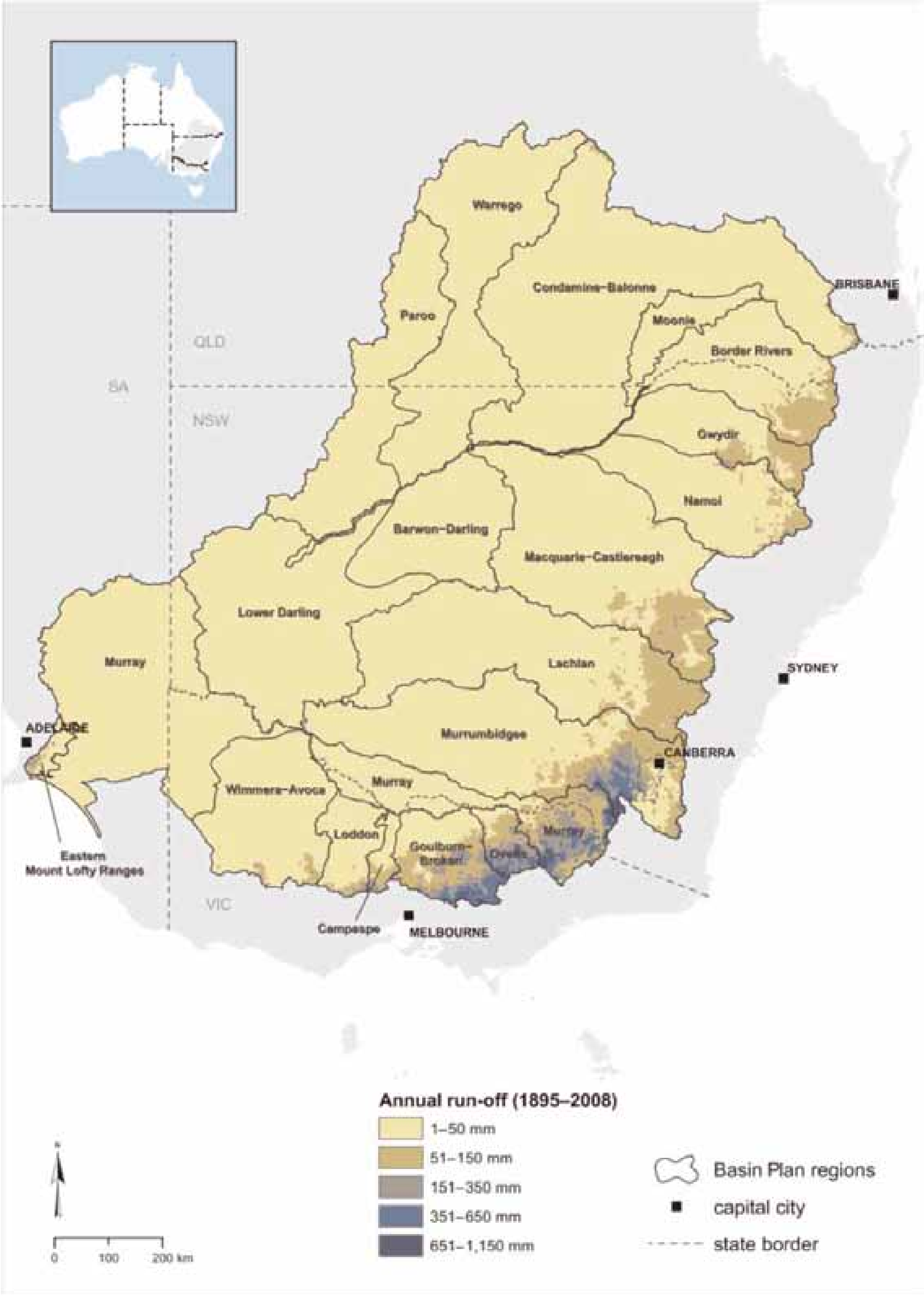

Figure 1-1: Overview map of the Murray-Darling Basin including annual run-off.

Source: Mean annual run-off modelled using the method in the CSIRO Murray-Darling Basin Sustainable Yields Project (Chiew et al. 2008; CSIRO 2008), cited in Figure 2.3 MDBA (2010c)

The last major tributary of the River Murray is the Darling River which joins the River Murray just upstream of the Wentworth Weir (and Lock 10). Lock 10 is located just over 832 river kilometres from the Murray Mouth. The Murray enters the Southern Ocean at the Murray Mouth near Goolwa, having first flowed through Lake Alexandrina.

Below Wentworth, the river has a very low gradient (e.g. 89 per cent of the length of the river downstream of Wentworth has a channel slope of less than 0.017 centimetres per kilometre) with relatively little sinuosity, low stream power, and highly cohesive bank materials. Flow velocities are correspondingly slow and the travel time for water flowing from the South Australian border to the Lower Lakes is approximately one month. However, the actual travel time varies significantly between flow events and can be much shorter than this. At higher flow rates travel time is usually reduced but this is highly variable and dependent on such factors as the rate of rise of a flood peak and the rate of flow. For example, in the 2010–11 floods the time for flow between locks was in the order of three days (D Jones 2011, pers. comm., 13 April). Travel time from Lock 1 to Wellington (200 river kilometres) at flows less than 50,000 ML/day would typically take around three days (D Jones 2010, pers. comm., 5 December).

There are three distinct sections of river downstream of the Darling River confluence. Thoms et al. (2000) describe the river from Wentworth to Overland Corner as being situated in a 5 to 10 kilometre-wide valley, with the channel flanked by a broad floodplain. From Overland Corner to Mannum the river channel is confined to a limestone gorge 2 to 3 kilometres wide and 30 to 40 metres deep. Flows in the lower sections of the River Murray are therefore slow moving and the lateral extent of flooding is constrained by the limestone gorge. From Mannum the river passes through swamplands before reaching Lake Alexandrina.

Flows in the lower sections of the River Murray are heavily regulated. Upstream of the South Australian border, flows are managed through the large water storages (mainly Hume Dam, Dartmouth Dam, Menindee Lakes and Lake Victoria). The river is further regulated by weirs with associated locks, which allow boat passage past the weirs. Weirs are used to maintain stable water levels along the lower sections of the River Murray. The last of these weirs and associated locks is Lock 1 which is located at Blanchetown in South Australia. Lock 1 represents the upstream boundary of the area of interest for this water delivery document, which focuses on the area downstream of Lock 1.

There are two other key features in this area: Lake Albert and the Coorong. Lake Albert is a terminal lake connected to Lake Alexandrina by a narrow channel. Lake Albert and Lake Alexandrina are often referred to as the Lower Lakes. The Coorong is a 140 kilometre long lagoon system that receives inflows from Lake Alexandrina, the Southern Ocean and the upper south-east area of South Australia. The Coorong and Lower Lakes were designated as wetlands of international importance under the Ramsar Convention in 1985. The Coorong, Murray Mouth and Lower Lakes are proposed as a hydrological indicator site in the Murray-Darling Basin having met all five of the Murray-Darling Basin Authority (MDBA) key proposed environmental asset criteria (MDBA 2010). They are also an icon site under The Living Murray initiative.

There are five barrages that separate Lake Alexandrina from the Coorong and the Murray Estuary—Goolwa, Mundoo, Boundary Creek, Ewe Island and Tauwitchere. With the exception of Goolwa, the barrages are built on a natural sill of calcium sediments (the remnants of the last interglacial shoreline), which separates Lakes Alexandrina and Albert from the Murray Estuary and the Coorong (Gell & Hayes 2005). Historically, this sill, in conjunction with flow down the River Murray, is hypothesised to have impeded the ingress of seawater into the Lower Lakes in addition to the Murray Mouth itself acting as a constriction reducing the effect of local tides. Built by the Engineering and Water Supply Department of South Australia for the River Murray Commission between 1930 and 1940, the barrages are constructed from reinforced concrete and have 593 independent operable gates (Phillips & Muller 2006).

Figure 1-2: Regional context for Coorong, Lower Lakes and lower River Murray.

(Source: SEWPaC 2011)

SA Water operates the barrages for, and on behalf of, the governments of South Australia, New South Wales, Queensland, Victoria and Australia, subject to funding and direction from the Murray-Darling Basin Authority (MDBA). Water released from Lake Alexandrina through the barrages exports salt, sediment, nutrients and organic matter to the Coorong and Southern Ocean and facilitates the movement of fish species between the Basin and the ocean.

The barrages maintain a weir pool from Lock 1 at Blanchetown to the Lower Lakes, a distance of about 270 kilometres. This weir pool supports the four major public water supply pumping stations that are located downstream of Lock 1. These supply the Swan Reach to Stockwell, Mannum to Adelaide, Murray Bridge to Onkaparinga, and Tailem Bend to Keith pipelines which provide water to Adelaide, parts of the mid-north and Yorke Peninsula, and the south-east of South Australia. The weir pool also provides water that is directly extracted for town supply and agriculture around the Lower Lakes and River Murray up to Lock 1.

1.3 River operating environment

1.3.1 Overview

Inflows to this section of river are primarily governed by River Murray flows past Lock 1 and these in turn are governed by the flow to South Australia.

There are opportunities to manipulate flows to South Australia by the management of Lake Victoria (and storages further upstream), but once below Lake Victoria the only opportunities to manipulate flows are though weir pool manipulations. While these can be effective in managing water levels and spatial spread of water for flows below 50,000 ML/day (the maximum river discharge at which weirs 3 and 5 can be elevated—with lower volumes for the rest of weirs (Cooling 2010)), their impact on actual flows are very limited (due to the relatively small storage volume behind each lock and weir).

For much of the time the water level in the River Murray below Lock 1 is controlled by the water level in Lake Alexandrina and levels are relatively stable. The river level does vary through flooding and drying events, and with wind direction and strength or seiching, exposing and inundating the river margin and connected wetlands, on a seasonal and short-term irregular basis.

Historically, the key water levels in the Lower Lakes, measured by metres with respect to the Australian height datum (mAHD), have been:

- +0.60 mAHD: preferred minimum level
- +0.75 mAHD: target full supply level (FSL)
- +0.85 mAHD: surcharge level (water begins to spill over the spillways associated with the barrages as surcharge level is achieved)
- +0.87 mAHD: inundation of surrounding land commences.

Past management of lake levels primarily focused on meeting the requirements of water extractors, and subsequently compromised the environmental values of the Lower Lakes. The need to adopt operational arrangements that better meet the ecological need of the area has been recognised. Strategies have been proposed that would permit more variable inter and intra-annual lake levels (MDBC 2006).

Under typical conditions (i.e. those prior to winter 2006, after which time the combined drought and river regulation impacted upon water levels), Lakes Alexandrina and Albert fill during winter/spring from a low of approximately +0.60 mAHD, typically attained in April/May, to a high of +0.75 mAHD (FSL). If inflows are adequate, the lakes are surcharged to +0.85 mAHD by the end of spring, primarily for water supply purposes to prevent lake levels falling below +0.60 mAHD in the following autumn as water is lost through evaporation. Some incidental watering of fringing wetlands may have occurred through this process. This process (in combination with grazing practices) also contributed to accelerated lake shore erosion causing detriment to some wetland areas and loss of farming land.

Water in the Lower Lakes has been maintained above +0.60 mAHD to:

- Minimise the ingress of seawater into the lakes via the barrages.
- Reduce the potential for saline groundwater discharge into the lakes.
- Facilitate irrigation diversions (but this is no longer critical since the construction of pipelines around both sides of the Lower Lakes in response to the recent drought).

Saline groundwater intrusion and acid sulphate soils can present management issues at thresholds below +0.6 mAHD. These are further detailed in Section 1.3.3.

Wind effects can result in localised water levels ± 0.30 metres different from the average for the Lower Lakes as a whole (Webster et al. 1997).

The flow through the barrages separating the Coorong from Lake Alexandrina can be controlled individually by raising or lowering gates, but for low flow periods, particularly over summer when evaporation rates are high there can be extended periods of zero flow and occasionally seawater can leak through the barrages or splash over them creating localised areas of salty water over short periods of time. Releases of water depend very much on flow conditions in the River Murray and in recent years these flows have been reduced due to drought conditions. Most releases occur through the three main barrages namely Goolwa, Ewe Island and Tauwitchere (Webster 2007).

In recent years additional discharge to the Coorong has occurred through Salt Creek, near the southern end of the South Lagoon. This water is surface drainage water from the upper south-east drainage scheme (USED) that has been collected via a network of channels into Morella Basin where it is stored. The inflow volumes from this source have been minor in comparison to the volume of the Coorong and the volumes of historic flows through the barrages.

Within the body of the North Lagoon, at weather timescales (10 days or less), water level variations are driven in equal measure by wind, which tilts the water level one way or another depending on wind direction, and by sea level variations (Webster 2007). Tidal water level variations at the diurnal and semi-diurnal frequencies are thought to dominate within approximately 15 kilometres from the mouth, but the importance of these depends very much on the degree to which the mouth channel is open (Webster 2007). The depth of the Murray Mouth channel is clearly related to outflow rates through the mouth (Webster 2007). When the mouth is constricted, fluctuations in sea level penetrates less effectively into the Coorong and the exchange flows associated with these fluctuations are reduced. As a consequence, mixing of salt back towards the mouth is less effective and salinity tends to increase in both lagoons.

There are several channel sections on either side of Parnka Point that are very narrow (approximately 100 metres) and shallow, which represent the main restriction for water exchange between the two lagoons. This limits the movement of water between the North and South Lagoons resulting in a markedly higher salinity in the South Lagoon.

A more detailed description of the operating environment for each key system component follows.

1.3.2 River Murray: Lock 1 to Wellington

The section of river below Lock 1 extends 200 river kilometres south before it flows into Lake Alexandrina which is five kilometres south of the township of Wellington. Lock 1 and the associated weir were completed in 1922. This infrastructure maintains the water level upstream of the weir at 3.20 mAHD. A fishway was constructed in 2009 at Lock 1 to facilitate fish passage past the weir.

Between Lock 1 and Mannum the River Murray is confined to a limestone gorge two to three kilometres wide and thirty to forty metres deep (Thoms et al. 2000) and the floodplain is relatively limited in extent (Ecological Associates 2010a). From Mannum the river passes through swamplands before reaching Lake Alexandrina. This section of the River Murray receives minor inflows from Reedy Creek (near Mannum) and Marne River (south of Swan Reach).

Lock 1 and its associated weir are operated to maintain a target pool level for irrigation and navigation. A constant level is maintained at a variety of flows by varying the passing flow. As flows increase during a flood, opening the weir or removing stop logs increases the passing flow. The weir is closed or stop logs are replaced as flows decrease. Under flood flow Weir 1 is generally removed between flows of 49,000 and 59,000 ML/day to allow flood flows to pass downstream. The weir is usually reinstated at flows representing the recession of the flood peak (from 74,000 to 84,000 ML/day) (Cooling 2010).

As flow over Lock 1 increases, the river surface slopes as it flows downstream from the weir towards the barrages. This slope increases as flow increases. Back waters and fringing wetlands are supplied with water as the water level below the lock increases. While most of these wetlands are connected directly to the river (at normal pool level) some have regulator structures on them and can be manipulated to create wetting and drying cycles as well as to hold water post flood recession.

There are a few temporary wetlands inundated once flows exceed 30,000 ML/day but the volumes of water needed to fill these is small and hence these are not the primary focus for this water delivery document. The management of these smaller systems are either done by the South Australia Murray-Darling Basin Natural Resources Management Board or by community groups under guidance from the BoardFloodplain inundation between Lock 1 and Wellington commences at flows above 55,000 ML/day and significant inundation occurs at 75,000 ML/day (Ecological Associates 2010).

For much of the time, in the absence of high river flows (e.g. less than 30,000 ML/day), water level in the lower sections of the river is controlled by the water level in Lake Alexandrina and levels are relatively stable (Lake Alexandrina has been typically maintained at a level of +0.6 to +0.85 mAHD). River level does vary through flooding and drying events, and with wind direction and strength, or seiching, it exposes and inundates the river margin and connected wetlands on a seasonal and short-term irregular basis.

During high flows water levels downstream of the Lock 1 weir increase with flow, but the effect diminishes with distance.

After barrage construction, and as a consequence of floodplain development for irrigation, much of this river section developed an ecological character very different from its historical condition. The maintenance of relatively stable water levels has reduced habitat heterogeneity (Phillips & Muller 2006). In the past it has been important to maintain stable water levels in the Lower Lakes for water supply and ferry operation purposes. These requirements are now largely met over a wider range of water levels than in the past as a result of infrastructure that was installed in response to the recent drought.

The main channel and connected wetlands are thus highly regulated by the barrages, and through stream regulation, upstream of Lock 1.

1.3.3 The Lower Lakes

The Lower Lakes are large, freshwater lakes, physically separated from the Murray Mouth and estuary and the Coorong by a series of islands and the system of five barrages. The barrages were designed to exclude seawater from the Lower Lakes and to regulate lake water levels in spite of upstream development (Sim & Muller 2004).

Construction of the barrages caused a barrier to fish migration. Fish movement from the lakes to the Coorong remained possible but was restricted to periods when the barrage gates were open. Movement in the reverse direction was restricted due to the high flow velocities and physical structure of the gates. Such movement is particularly important for diadromous and migratory species that require access to both marine and freshwater habitats to complete their life cycles, and to freshwater vagrants that may be washed downstream and need to return to freshwater habitats (Jennings et al. 2008). Since 2002, five fishways have been constructed to facilitate fish passage. A rock ramp fishway and two vertical slot fishways are located at the Tauwitchere Barrage and vertical slot fishways are located at the Goolwa Barrage and Hunters Creek. The MDBA Fish Passage Taskforce has also recommended fishways at Mundoo and Boundary Creek barrages. Recent 2010–11 monitoring indicates that fishways have effectively enabled passage of a large abundance and diversity of fish, including size ranges (A Frears (DFW) 2011, pers. comm.).

Water levels in the Lower Lakes fluctuate seasonally—they are generally higher in late spring and lower in late summer/autumn because of seasonal variability in the River Murray and smaller local tributary inflows, as well as climatic factors such as evaporation (Phillips & Muller 2006).

Under current conditions, long-term average annual outflows through the Murray Mouth have been estimated to be around 5,100 GL/year, but more recently the three-year rolling average for 2006–07 to 2008–09 was 100 gigalitres (MDBA 2010).

There are a number of small tributaries from the Eastern Mount Lofty Ranges (the main ones being the Finniss River, Currency Creek and the Angas and Bremer Rivers) that contribute inflows to Lake Alexandrina of 35 to 110 GL/year, with a median inflow of 50 to 60 GL/year (DEH 2010). While these are minor in volume they are considered ecologically important because they support species listed under the *Environment Protection and Biodiversity Conservation Act 1999* (Cwlth) (EPBC), and species of conservation significance to South Australia.

Until recently town and irrigation supplies were taken directly from the Lower Lakes. Extreme low water levels (less than 0.0 mAHD) between 2007 and 2010 resulted in water supply pipelines being constructed along both sides of Lakes Alexandrina and Albert. This has removed the need for most irrigators to rely directly on water extraction from the lakes. Water for these irrigators and for town supply is now extracted from upstream of the lakes on the River Murray near Tailem Bend. When lake levels are high enough and water quality appropriate it is cheaper for irrigators to extract water directly from the lakes, and some still prefer to do so.

Both Lake Alexandrina and Lake Albert, and many of the wetlands along the River Murray floodplain between Lock 1 and Wellington, have potentially high levels of acid sulfate soils (ASS) (Fitzpatrick et al. 2008a, 2008b, 2009). Water levels in the Lower Lakes below 0.0 mAHD will expose ASS, creating the potential for pH to decline below Australian and New Zealand Environment Conservation Council guideline levels (ANZECC 2000). This has implications for the maintenance of the ecological character of the water body and individual wetlands. If low water levels allowed sufficient acidification of ASS in the lakes for the alkalinity buffer in the remaining lake water to be lost, and the pH shifted below 6.5, then a suite of flora and fauna could be put at risk.

Saline groundwater underlies the Lower Lakes and can impact on water quality, however groundwater inflow volumes are believed to be negligible compared with river inflows (Lester, Fairweather & Higham 2011a). The most significant risk to salinity levels in the Lower Lakes is low inflows from upstream (resulting in a lack of dilution flows and low water levels leading to evapo-concentration), rather than groundwater inflow.

Shallow saline aquifers impact on the northern and eastern sides of Lake Alexandrina and on Lake Albert (Figure 1-3). On the western side of Lake Alexandrina, the watertable is within Quaternary clay which overlies and semi-confines the limestone aquifer (Haese et al. 2009). Elsewhere in low-lying areas around the Lower Lakes, the watertable occurs in organic-rich clays, which were deposited when the Lower Lakes expanded in response to a higher sea level about 6,000 years ago (Haese et al. 2009). These low-lying areas contain highly saline groundwater (where salinity is greater than 100,000 milligrams per litre) due to strong evaporative discharge, which has lowered the watertable below sea level (Haese et al. 2009). The watertable contours show that these areas are the focus for regional groundwater discharge in preference to the Lower Lakes when the lakes are at a higher level of +0.75 mAHD. The risk of salinisation is most prevalent where depth to the watertable is less than 2 metres. Mean monthly salt inflows from groundwater into Lake Alexandria vary between 300 and 800 tonnes per day (Heneker 2010).

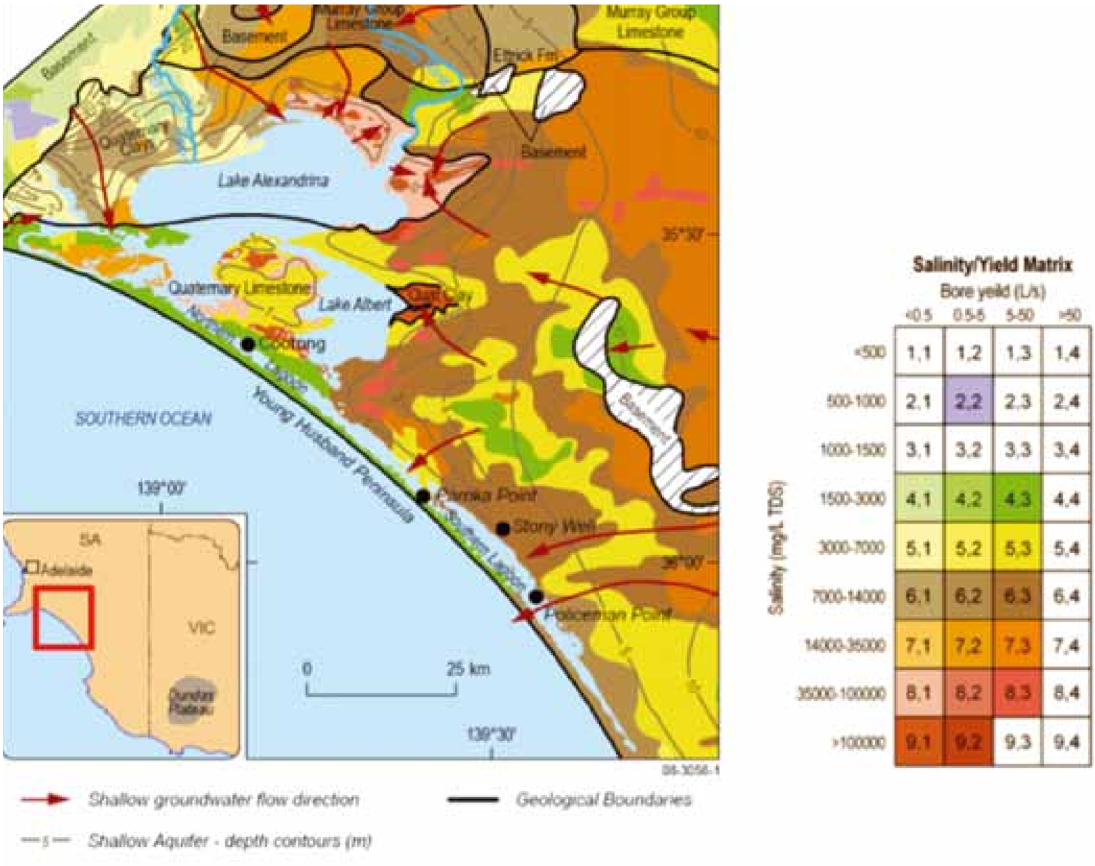

Figure 1-3: Hydrogeological map of the Coorong Lagoon and Lower Lakes region.

(Source: Haese, Murray & Wallace 2009)

Lake Alexandrina is a broad and shallow (mean depth 2.86 metres, maximum depth 4.75 metres), well-mixed, freshwater, regulated waterbody, with a surface area of approximately 650 square kilometres and volume of approximately 1,620 gigalitres at +0.75 mAHD. It is a large open water body that supports little or no macrophyte vegetation beyond a depth of approximately 0.5 metres. It is likely that high turbidity, water movement, carp and excessive depth all contribute to an unfavourable environment for submerged, floating-leaved and emergent macrophytes.

Depth volume and area information for Lake Alexandrina and Lake Albert is provided in Appendix 5.

The level of Lake Alexandrina is highly regulated by the five barrages that separate the lake from the Coorong. Average water levels have historically been maintained at between +0.60 and +0.85 mAHD (Figure 1-4). The lake levels vary seasonally with flooding and drying events, and in the short-term with wind direction and strength, and seiching. Together, these processes expose and inundate the lake margin, on both a seasonal and a short-term irregular basis. Water levels at any one time may vary across the lake by as much as 0.6 metres as a consequence of wind strength and seiching. Lake Alexandrina is a freshwater system, with salinity usually varying between 400 and 1,500 electrical conductivity units (EC) (Phillips & Muller 2006; Heneker 2010). Salinity in Lake Alexandrina is primarily controlled by lake inflows from the River Murray and Eastern Mount Lofty Ranges' (EMLR) tributaries, and outflows through the barrages (Heneker 2010).

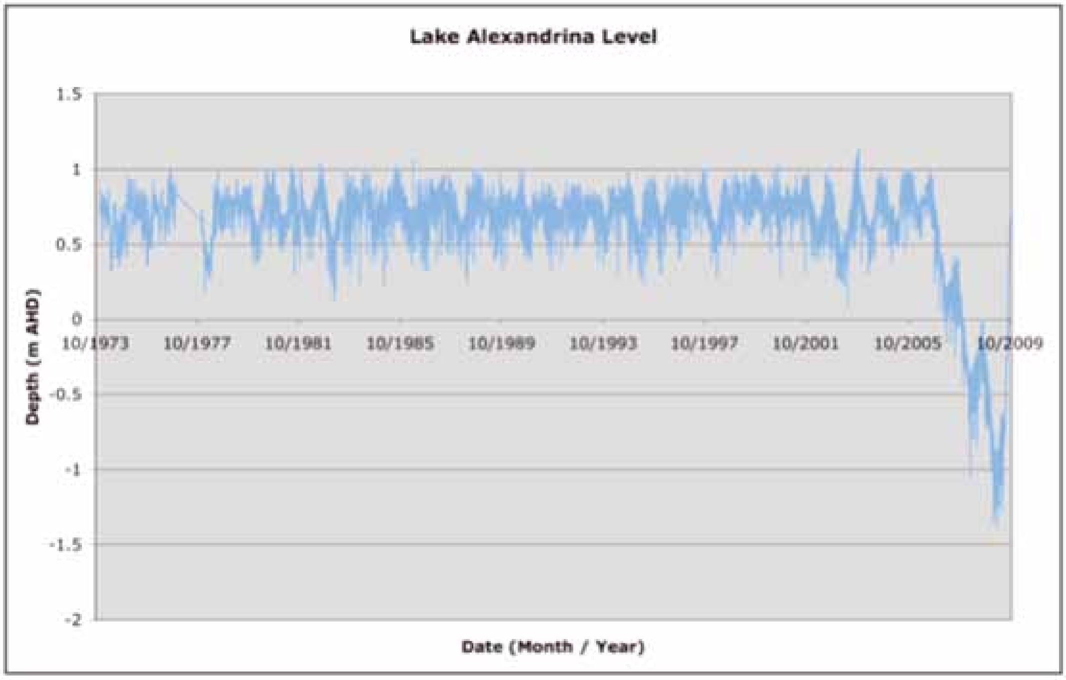

Figure 1-4: Lake level (mAHD) of Lake Alexandrina at the Goolwa Barrage (Site A4261005 Upstream Goolwa Barrage Daily) November 2002 to November 2009.

(Source: DWLBC)

Lake Albert is a terminal lake of the River Murray linked to Lake Alexandrina by a narrow channel (The Narrung Narrows) between Point Malcolm and Narrung Peninsula, via which it receives the majority of its inflows. The lake is broad and shallow, a maximum depth 1.7 metres and covers an area of 168 square kilometres. Like Lake Alexandrina, it is an open water body that supports little or no macrophyte vegetation beyond a depth of approximately 0.5 metres.

Water levels in Lake Albert are governed by the water levels in Lake Alexandrina and also by wind and evaporation. During the recent extended period of low flow into the two lakes (spring 2006 to spring 2010), the lakes were separated by a temporary bund (2008 to 2010), to allow control of water levels in Lake Albert. This bund was removed in 2011.

The lake supports complex and extensive fringing vegetation and an array of sand and mud islands, providing important habitat to a variety of bird species (Seaman 2003). In the recent drought, and as a consequence of the record low flow into the lake and the historic low lake levels, much of this fringing habitat was disconnected from the lake shoreline for an extended period, effectively removing habitat from the lake for many fauna species. The subsequent exposure of mud flats fringing the lake created extensive foraging habitat for migratory waders (Ecological Associates 2010b).

A shallow and saline aquifer (Figure 1-3) also discharges into the lake (Heneker 2010), particularly during periods of low water levels, creating seasonal and permanent saltwater marshes in depressions or swales around the lake's edge (Phillips & Muller 2006).

Lake Albert acts as a sink for salt and sediment for inflows from the River Murray and groundwater (Phillips & Muller 2006). As a terminal lake it has no through-flow mechanism and consequently is more saline than Lake Alexandrina (Heneker 2010). Salinities typically range between 1,000 to 2,300 EC (Heneker 2010), but can be higher. It is not practical to manage salinity levels within Lake Albert independently of Lake Alexandrina (Heneker 2010).

Extensive siltation from river inflows and lakeshore erosion is reducing water depth and topographical diversity (Aldridge et al. 2009). This has resulted in a retreat of lake perimeter at an average of 1 metre per year (Coulter, 1992), with deposition rates of around 3 millimetres per year (Herzeg et al. 2001). The nature of Lake Albert, as a terminal lake with its narrow connection with Lake Alexandrina, means that flow into and out of this lake is controlled by water level, wind and evaporation. Prior to European settlement, Lake Albert is believed to have been significantly fresher than today, supporting relatively extensive submerged aquatic plant beds and diverse emergent fringing vegetation communities (Sim & Muller 2004).

Before river regulation the Lower Lakes are believed to have been essentially an estuarine and freshwater system, with freshwater submerged aquatic plants extensive in Lake Alexandrina, spreading for several kilometres into the lake (Sim & Muller 2004). These habitat types are now restricted to the lake fringe and EMLR tributary deltas. Lake Alexandrina has developed an ecological character different from its pre-regulation condition.

After barrage construction, as a consequence of the maintenance of relatively stable water levels, the lake habitat heterogeneity has been reduced, with the extent of fringing and emergent vegetation significantly contracted when compared with historical values, and communities such as *Phragmites australis* and *Typha domingensis* have flourished while species dependent on variable water levels (E.g. *Eleocharis* spp and *Baumea* spp) have become restricted to fringing wetlands and tributaries (Phillips & Muller 2006).

1.3.4 Murray Estuary

The Murray Estuary (area approximately 3,400 hectares) includes the region around the Murray Mouth from the Goolwa barrage to Pelican Point and the Goolwa, Coorong and Mundoo channels which are separated from Lake Alexandrina by the Goolwa, Boundary Creek, Mundoo, Ewe Island and Tauwitchere Barrages.

The area is naturally estuarine. Salinity levels fluctuate widely when there is flow across the barrages. When flow ceases, a salinity gradient from seawater at the mouth to hypersaline conditions in the Northern Lagoon, develops (Lester et al. 2011b).

A diurnal tidal prism is evident as far as Pelican Point, but it is relatively small in extent, with the deepest mouth channel attenuating the largest tides (approximately 1 metre range for spring tides) by a factor of three by the Tauwicherie Barrages compared with that in the nearby sea (Webster 2007).

The Murray Mouth has always been relatively narrow, but it has been and continues to be extremely dynamic (Webster 2005). The width of the mouth has varied from being several hundred metres during flood flows (Walker 2002), to closed off completely in 1981 and almost closed in 2003. The degree of opening of the Murray Mouth is governed by a flood-tide delta (a delta landward of the mouth) that is present in the estuary and is formed as a result of the micro-tidal conditions and domination of wave energy along the coast (Harvey 1996). Modelling indicates that barrage outflows are the controlling agent for maintaining the mouth in an open condition (Webster 2007). River Murray flows over the barrages maintain an open mouth by exporting accumulated silt from the tidal sedimentation imbalance (more silt is imported from the incoming tide than is exported by the outgoing tide). The channel is subject to infilling and scouring on a seasonal basis. The frequency and duration of periods of zero or very low river flows since 2002 has meant that this imbalance has not been redressed naturally, and the mouth began to close. From October 2002 to December 2010 the mouth was kept open by dredging. Long-term effects of high flow events are not seen, as the majority of freshwater passes through the mouth, and seasonal siltation processes do not allow a deep mouth to persist through time.

Maintenance of an open Murray Mouth is important as many species depend on movement from the ocean into the estuary and freshwater Lower Lakes for reproduction and recruitment (MDBC & DWLBC 2002). An open mouth is also vital to the Coorong's ecosystem, as the tidal variation provides habitat for waders and maintains water levels and salinity for many other species.

Modelling (MSM-Bigmod) of River Murray natural series flows (for the period 1891 to 2000) over the barrages and out of the mouth, found that flows exceeding 2,000 ML/day would have occurred more than 95 per cent of the time (Sim & Muller 2004). This is no longer the case with much reduced flows over the barrages and extended periods of no flows leading to the constriction of the Murray Mouth.

1.3.5 The Coorong

The Coorong is a coastal lagoon complex separated from Encounter Bay and the Southern Ocean by two narrow coastal dune barriers, the Younghusband Peninsula to the southeast and the Sir Richard Peninsula to the northwest of the Murray Mouth.

The system is classified as an inverse estuary, which means that freshwater inflows enter from the same end as the mouth, rather than the more-usual configuration of having fresh inflows enter at the opposite end to the connection to the sea. The terminal set of lagoons that form the Coorong gradually grade up over its length becoming progressively shallower towards the southern end of the Southern Lagoon before forming a series of ephemeral lagoons. This creates a salinity gradient from usually estuarine conditions around the Murray Mouth through to hypersaline conditions in the South Lagoon.

The Coorong receives seawater inputs via tidal exchange through the Murray Mouth, which is the main mechanism by which seawater enters and leaves the Coorong, and it receives freshwater input from River Murray flows over the barrages into the Goolwa and Coorong Channels (Figure 1-5).

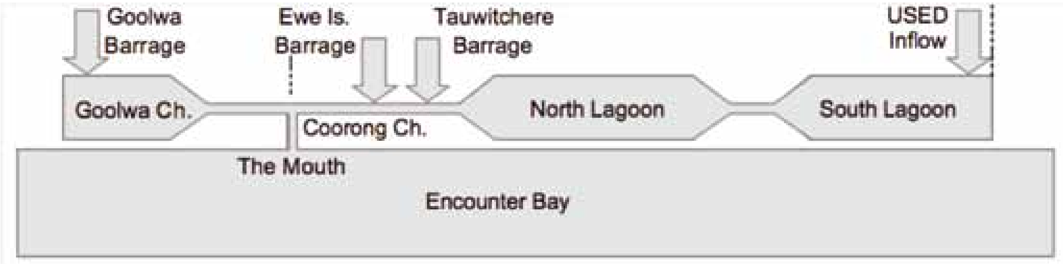

Figure 1-5: Summary of Coorong connectedness, including inflows.

(Source: Webster 2007)

Fresh water also enters the Coorong by distributed local run-off, groundwater inputs and small, irregular volumes of water from the Upper South East Drainage Scheme (USED Scheme) via Salt Creek located at the southern end of the Coorong system.

The conceptual model that underlies water movement and salt balance in this estuary type is illustrated in Figure 1-6 and Figure 1-7 (Webster 2006). Water is lost from along the length of the estuary through evaporation. To maintain the water level within the estuary, seawater flows in either from the estuary mouth or from flows over the barrages. The salt that is carried with the seawater tends to accumulate within the estuary. Back-and-forth water motions (oscillatory flows) within the estuary arise due to sea-level variations including the tides as well as water mounding due to varying winds blowing over the water surface. These motions serve to mix the salt accumulating within the estuary back towards its mouth (long-channel mixing). Over the long term the inflow of salt associated with evaporated water loss balances the transport of salt in the opposite direction due to oscillatory mixing. Super-imposed on this model of long-term salt transport within the Coorong are seasonal variations associated with the annual cycle of sea-level variation, relatively fresh water inflows from the River Murray over the barrages, and of evaporation (and precipitation) rate, but fundamentally this underlying salt balance pertains on an average basis (Lester et al. 2011b).

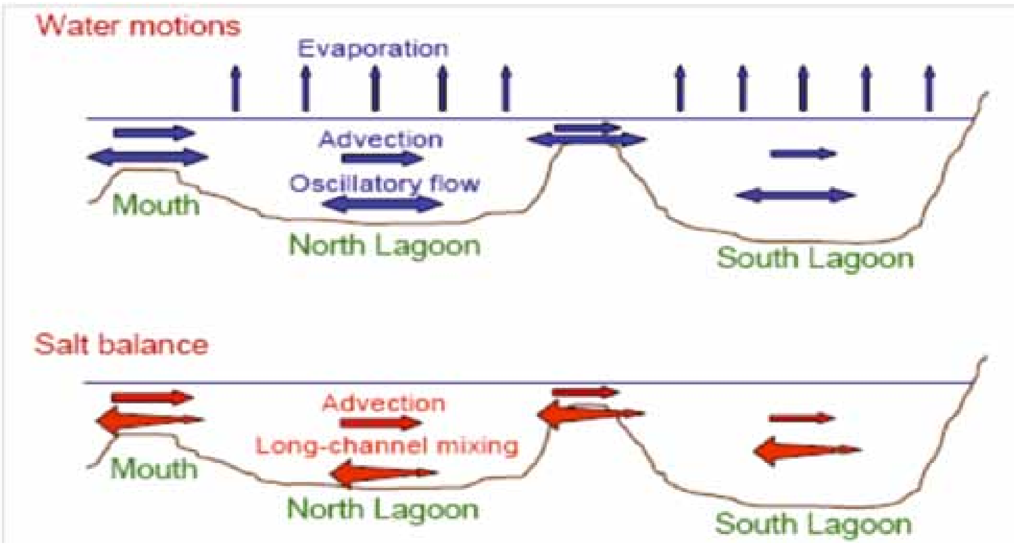

Figure 1-6 : Conceptual model of the Coorong.

(Source: Webster 2006)

Water levels in the Coorong undergo a seasonal cycle of up to approximately 0.7 metres in range, higher levels tending to occur in late winter to early spring and lower in late summer to early autumn (Webster 2005). This seasonal variation is due to a combination of variation in sea level outside the mouth, seasonal variations between the two lagoons and the back-up due to discharge through the barrages. Webster (2005) also found that shorter term water level variations of ±0.05 metres in the Coorong are typically due to the tilting of the water surface by the wind (Figure 1-7). Tidal level variation is important near the mouth.

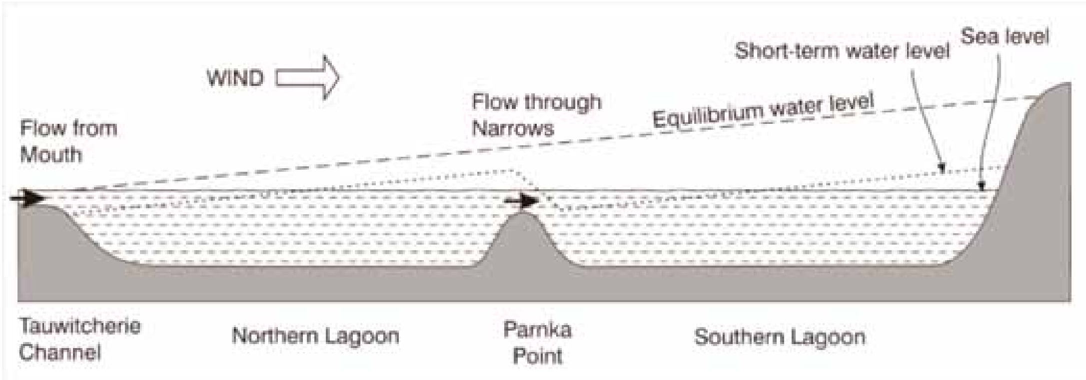

Figure 1-7: Water level response in the Coorong to an along channel (south easterly wind) wind stress.

(Source: Webster 2005)

The movement of water in and out of the South Lagoon associated with seasonal water level variation is a key determinant of the salinity there (Webster 2005).

Flows over the barrages maintain water levels within the Coorong at a higher level than the sea level in Encounter Bay (Webster 2005). This reduces seasonal disconnections between the lagoons and thus enhances long-channel mixing within the system, tending to result in higher water levels and lower salinities. In addition, the water that flows along the Coorong to replace evaporative loss has a lower salinity than seawater, so the overall input of salt into the system is lower, again reducing the salinity of Coorong waters.

Webster (2007) found that the barrage flows influence the salinity dynamics in the Coorong in at least three important ways. Periods of elevated barrage flows deepen the mouth channel which in turns allows more active mixing along the length of the Coorong. By freshening the water at the northern end of the North Lagoon (compared to seawater) the water that flows along the Coorong to replace evaporative losses has a lower salinity. When the barrages flow, the water level in the whole system tends to increase and water is pushed along the Coorong. Webster found that, generally, variations in discharge cause the water level in the Coorong to rise and fall causing back-and-forth water exchange along the system, which enhances longitudinal mixing.

For barrage flows less than 1,225 GL/year there is a high likelihood that the entire Coorong will fall into degraded ecosystem states, with more than 6,000 GL/year required to minimise the likelihood of more than 50 per cent of sites being in a degraded ecosystem state (Lester et al. 2011b).

Key characteristics for the north and south lagoons are further described in the sections that follow.

1.3.5.1 North Lagoon

Water quality in the North Lagoon has recently been characterised by similar conditions as presented in the Murray Estuary (Dittman et al. 2006), with barrage releases controlling salinity. Typically, the salinity gradient increases southwards along the North Lagoon, which extends from Pelican Point to Parnka Point. The Coorong naturally splits into North and South Lagoons at Parnka Point, where it reduces to a 100 metre wide section (Hells Gate). There are several channel sections on either side of Parnka Point that are very narrow (approximately 100 metres) and shallow, and that represent the main restriction for water exchange between the two lagoons (Webster 2007). The distance from the southerly end of the North Lagoon to the mouth is approximately 60 kilometres (Webster 2007). At 0 mAHD, the average width of the North Lagoon is 1.5 kilometres, the average depth is 1.2 metres, the volume of the North Lagoon is 86 gigalitres (Webster 2007) and its area is approximately 11,069 hectares (Phillips & Muller 2006).

Prior to barrage construction the North Lagoon was dominated by tidal input of marine water and River Murray inputs at its northern end (Gell & Haynes 2005), but since then the extent of estuarine habitat has been severely reduced, with a transition to higher turbidity and hypersaline conditions, and the loss of extensive beds of submerged vegetation, which was naturally dominated by *Ruppia megacarpa* (Phillips & Muller 2006).

Although the North Lagoon is a permanent water body, the area of inundation varies both diurnally and seasonally with the tides and inflows, resulting in the exposure of mudflats and intertidal marshes along the shoreline (Boon 2000). This area provides important habitat for a large number of waterbirds, including migratory shorebirds in spring and summer (Paton et al. 2009; Paton 2010).

1.3.5.2 South Lagoon

South of Parnka Point, the South Lagoon extends past Salt Creek where it ultimately becomes a series of hypersaline ephemeral lagoons to the south. The length of the South Lagoon is approximately 40 kilometres (Webster 2007). At 0 mAHD, the average width of South Lagoon is 2.5 kilometres and the average depth is 1.4 metres, the volume of the Lagoon is 140 gigalitres (Webster 2005) and it has an area of approximately 9,440 hectares (Phillips & Muller 2006).

Typically, water levels within the South Lagoon vary seasonally by approximately 0.9 metres (Lamontagne et al. 2004), being higher in winter and lower in summer, resulting in the seasonal exposure of mudflats which provide extensive areas of foraging and nesting habitat for large numbers of birds (Phillips & Muller 2006).

Salinity levels vary from estuarine to hypersaline. Salinity in the South Lagoon is controlled by the exchange of water with the North Lagoon, rainfall on the lagoon surface, evaporation, openness of the Murray Mouth, the depth of channels at Hells Gate, and inflows from Salt Creek (from the USED scheme).

During the summer months, the water level in the Coorong drops as sea level drops and barrage flows diminish (Webster 2005). Once the water level drops to 0 mAHD, the channel connecting the lagoons becomes shallow enough that it cannot support a flow sufficient to replenish the evaporation loss from the South Lagoon (Webster 2007). Consequently, the water level in the South Lagoon continues to drop below the level in the North Lagoon. Under these conditions, water level in the South Lagoon is determined by both the evaporation rate and by the height of the Parnka Point channel bottom (Webster 2007).

1.3.5.2.1 Upper south-east dryland salinity and flood management program (USED scheme)

The upper south east is a region situated immediately east of the Southern Lagoon of the Coorong. The region features a drainage network designed to prevent saline groundwater from rising to the land surface and affecting the health of agricultural and native vegetation. Surface water is also captured within the drains and diverted away from the region. Morella Basin, near Salt Creek, is the receiving basin for all flows from the USED scheme. Water held within Morella Basin is released into the Southern Lagoon of the Coorong via Salt Creek.

Release volumes from 2000 to 2009 ranged from a low of 33.6 ML/year (2002) to a high of 13,660 ML/year (2003) (a mean of 6,619 ML/year). Release volumes for 2010 by the end of October were 21,317 megalitres. The salinity of water released from Morella (2000 to 2005: 6,685 to 59,673 EC; September 2009 to October 2010: 10,708 to 30,291 EC), has been much lower than that of the Southern Lagoon of the Coorong (up to 380,000 EC) (MDBC 2006).

The decision to release water from Morella Basin is currently based on factors independent of flows down the River Murray, and at the discretion of the South Australian Department for Water (DWLBC 2009). Considerations for decision include:

- a release should be considered in October while there is still some flow occurring through the south eastern floodways; this allows the release of the freshest water before evapo-concentration occurs
- if there is an extreme rainfall event, a release may be considered earlier
- if a dry year has occurred, a release may be postponed until December or January or cancelled.

Releases from the USED scheme can potentially contribute to the mitigation of hypersaline conditions in the Coorong, associated with low River Murray flows. However, release volumes in the long term will depend on the development of further infrastructure and seasonal outcomes in the south east of South Australia.

A conceptual flow diversion system in the upper south east, to maximise inflows to the Coorong, indicates that estimated annual inflows could vary between 1.5 and 161 gigalitres, depending on channel capacities and diversion routes, with median annual volumes of between 30 and 40 gigalitres (AWE 2009). It is uncertain whether this volume of water alone would have a significant impact on the condition of the South Lagoon and hence this source of water should only be considered as being potentially complementary and not an alternative to increased River Murray flows over the barrages.

2. Ecological values, processes and objectives

2.1 Introduction

The Coorong and Lakes Alexandrina and Albert (the Lower Lakes) are recognised both nationally and internationally as significant in their role in supporting critical aquatic ecosystems within the Murray-Darling Basin, and for providing habitat for migratory avifauna listed under various international agreements. This recognition includes:

- their designation as a wetland of international importance under the Ramsar Convention in 1985
- the designation of the Coorong National Park
- the identification of the Coorong, Lower Lakes and Murray Mouth as one of six designated icon sites in the Murray-Darling basin under The Living Murray initiative
- the identification of the Coorong, Murray Mouth and Lower Lakes as a proposed hydrological indicator site in the Murray-Darling Basin—these sites also meet all five of the Murray-Darling Basin Authority's (MDBA) proposed key environmental asset criteria.

Listed under the Ramsar Convention as 'The Coorong and Lakes Alexandrina and Albert Wetland', this asset meets eight of the nine Ramsar criteria used to quantify wetlands of international importance (Phillips & Muller 2006). The justification against these criteria includes:

- it represents a unique wetland system, with 23 different wetland types
- it partially supports the critically endangered swamps of the Fleurieu Peninsula ecological community and provides habitat for nine nationally endangered fauna and six nationally endangered flora specieit supports populations of 20 fish species, five bird species, one plant species and the vulnerable *Gahnia* spp. vegetation association important for maintaining the biological diversity of the region
- it supports 20 fish and 49 plant species at a critical stage in their life cycle, or provides refuge during adverse conditions; it supports large waterbird populations at times of 200,000 to 400,000 birds
- it regularly supports 16 species in numbers exceeding 1 per cent of the total species population
- it provides significant habitat for 49 fish species; and of these, 43 rely on it as an important source of food, spawning grounds, nursery and/or migration path (refer to the Australian Wetlands Database; http://www.environment.gov.au/water/topics/wetlands/database/index.html).

The Coorong, Murray Mouth and Lower Lakes also meet all five of the ecological values used to identify key environmental assets within the Murray-Darling Basin (Table 2-1).

Table 2-1: Summary of the key environmental asset values in the Coorong and Lakes Alexandrina and Albert identified by the Murray-Darling Basin Authority.

Criterion number	Description	Values
1	The asset is recognised in and/or is capable of supporting species listed in international agreements.	• Approximately 140,500 ha of the Coorong and Lakes Alexandrina and Albert were listed under the Convention on Wetlands of International Importance (the Ramsar Convention) in 1985. • The Coorong and Lower Lakes site meets eight of the nine nominating criteria for Ramsar listings (Phillips & Muller 2006). • Species listed in the Japan–Australia, China–Australia and/or Republic of Korea–Australia migratory bird agreements have been recorded at and are supported by the site.
2	The asset is natural or near-natural, rare or unique.	• The site consists of a unique mosaic of 23 Ramsar wetland types which include intertidal mud, sand or salt flats, coastal brackish/saline lagoons, permanent freshwater lakes, permanent freshwater marshes/pools, shrub-dominated wetlands, and water storage areas (Phillips & Muller 2006). • The site is unique in its wide representation of wetland types within the bioregion. • The site includes the only estuarine system in the Murray-Darling Basin.
3	The asset provides vital habitat.	• This site supports a large number of fish and bird species during critical stages of their life cycles. Of the 49 species of native fish recorded, 20 species utilise the site at critical stages of their life cycle. This includes seven diadromous fish species such as common galaxias and estuary perch that move between fresh, estuarine and marine waters at various stages of their life to breed (Phillips & Muller 2006). • A total of 77 bird species have been recorded at the site, most being waterbirds (Phillips & Muller 2006). The site is important as waterbird habitat at a global, national and state scale. Of these, 49 species of birds including 25 species listed under international migratory conservation agreements, rely on the wetland at critical life stages, such as migration stop-over, for breeding habitat or as refuge during times of drought. • This site is considered significant because of the diversity of its fish species and the diversity of their form, structure and breeding styles, including their migration habits between fresh, estuarine and marine waters (Phillips & Muller 2006).
4	The asset supports Commonwealth, state or territory-listed threatened species and/or ecological communities.	• The site supports species listed as threatened under Commonwealth and/or state legislation.

Criterion number	Description	Values
5	The asset supports, or is capable of supporting, significant biodiversity.	• The site is one of Australia's iconic wetlands and a biodiversity hot spot supporting critically endangered, threatened and vulnerable species and ecological communities. It also supports extensive and diverse waterbird, fish and plant assemblages, which are reliant on its complex mosaic of wetland types (Phillips & Muller 2006). • The Department of Sustainability, Environment, Water, Population and Communities has identified the Coorong as part of one of 15 national biodiversity hot spots. The biodiversity hot spot covers an area of South Australia's south-east and Victoria's south-west. • A significant number of waterbirds use this Ramsar site, at times reaching 200,000 to 400,000 individuals—far in excess of 20,000 or more waterbirds required to meet the Ramsar criteria (Phillips & Muller 2006). A number of species that frequent this site regularly occur in abundances greater than 1,000 individuals. Sixteen species of waterbirds have been recorded in numbers greater than 1 per cent of the global population, including the Cape Barren goose (*Cereopsis novaehollandiae*), curlew sandpiper (*Calidris ferruginea*), red-necked avocet (*Recurvirostra novaehollandiae*) and fairy tern (*Sterna nereis*) (Phillips & Muller 2006). • The site also supports the Gahnia sedgelands, Swamps of the Fleurieu Peninsula as well as several species of note that contribute to the site's biological diversity, including the Murray hardyhead (*Craterocephalus fluviatilis*), Yarra pygmy perch (*Nannoperca obscura*), southern bell frog (*Litoria raniformis*), Australasian bittern (*Botaurus poiciloptilus*) and hooded plover (*Thinornis rubricollis rubricollis*) (Phillips & Muller 2006).

(Source: MDBA 2010)

The Coorong, Lower Lakes and Murray Mouth supports 58 identified vegetation communities of which two ecological communities are listed under the *Environment Protection and Biodiversity Conservation Act 1999* (Cwlth) (EPBC Act); Gahnia sedgeland ecosystem, and the Swamps of the Fleurieu Peninsula. Based on a search of the Biological Database of South Australia (BDBSA) data set and published literature, the habitat types presently support 117 fauna species meriting a significant international (IUCN Red List), national (EPBC Act) or state (National Parks and Wildlife Act 1972) conservation rating (Appendix 4). These include 20 fish, 90 bird, three amphibian, one reptile and three mammal species.

The Coorong and Lower Lakes represents important breeding habitat for waterbirds. Brandis et al. (2009) found that there were 470 records of colonial waterbird breeding in the Murray-Darling Basin from 1899 to 2008, with breeding recorded in 115 unique wetlands. Of these wetlands the Coorong and Lower Lakes wetland complex ranked fifth in the total number of breeding events, with 34 known events in the period, making it one of the most important colonial waterbird wetland breeding sites in Australia.

The diversity in ecological character of the River Murray from Lock 1 to Wellington, Lower Lakes, and the Coorong, broadly consists of four freshwater habitat components (the main channel and fringing wetlands between Lock 1 to Wellington; Lake Alexandrina; Lake Albert; and tributary wetlands associated with the lower reaches of the Finniss River, Currency Creek and Tookayerta Creek), and three estuarine-saline components (Murray Mouth and estuary; North Coorong Lagoon; and South Coorong Lagoon). Descriptions of the ecological values of each of these components are below.

2.1.1 Lock 1 to Wellington

The area between Lock 1 and Wellington is comprised of two distinct geomorphic areas: the limestone Murray Gorge and associated limited floodplain; and the swamplands extending from Mannum to Wellington.

Between Lock 1 and Mannum, wetland and watercourse features make up more than one-third of the area of the river corridor. Over half of the wetlands are permanently inundated and most of the remaining wetland areas are inundated at flows of 30,000 ML/day (Ecological Associates 2010). Below Mannum there are eight wetlands more than 50 hectares in size, representing two-thirds of the total wetland area in this section of the river, but less than 10 per cent of the total number of wetlands. Most of the floodplain below Mannum has been highly modified from its natural state for irrigation and agriculture. All large wetlands are inundated at pool level and most wetlands are permanently inundated. Additional areas are inundated by flows exceeding 30,000 ML/day (Ecological Associates 2010).

These wetlands support remnants of diverse herbland and sedgeland vegetation communities in South Australia, and in doing so, support species of significant conservation status in South Australia. These include the critically endangered purple-spotted gudgeon (*Morgurnda adspersa)* (Hammer et al. 2009) and cryptic waterbird species, the little bittern (*Ixobrychus minutus dubius)*, latham's snipe (*Gallinago hardwickii*) and spotless crake (*Porzana tabuensis)*. These wetlands also support the species listed under the EPBC Act, including small-bodied fish, such as the Murray hardyhead, and migratory/cryptic waterbird species, such as the lewin's rail (*Lewinia pectoralis)* and painted snipe (*Rostratula australis)*.

Fluctuations in water level, due to wind seiching (also known as wind tides) contribute to the maintenance of these wetlands by increasing breadth of the littoral zone, transporting nutrients and providing flow, enhancing ecological diversity.

Two conservation parks are associated with the main river channel below Weir 1 (Mowantjie Willauwar Conservation Park (143 hectares) and Ngaut Ngaut Conservation Park (49 hectares)).

2.1.2 Lake Alexandrina

Lake Alexandrina supports a complex fringing vegetation, 14 wetland types (Table 2-2), ecologically valuable habitat on Hindmarsh Island, and an array of sand and mud islands providing important habitat to a variety of bird species (Seaman 2003). The lake supports extensive and highly significant *Phragmites australis* and *Typha domingensis* reedbeds, which provide excellent shelter habitat for a range of fish and other vertebrate species, as well as long-term waterbird rookeries for a range of species at a variety of sites around the lake perimeter (Phillips & Muller 2006). The most complex wetland flora is found near confluences, channels and drains where the localised water regime is relatively variable (Phillips & Muller 2006).

Three state game reserves (Currency Creek Game Reserve (128 hectares), Mud Islands Game Reserve (125 hectares) and Tolderol Game reserve (427 hectares)), one conservation park (Salt Lagoon Islands Conservation Park (76 hectares)) and the Mosquito Point Sanctuary, all established under the *National Parks and Wildlife Act 1972* (SA), are located around the perimeter of Lake Alexandrina. To the south, Lake Alexandrina abuts the Coorong National Park, and in 2001, the private property Wyndgate (a third of Hindmarsh Island) was added to the National Park.

Table 2-2: Overview of wetland habitat and community diversity across the Coorong and Lower Lakes Ramsar site.

Wetland types found within the Ramsar site	Freshwater			Estuarine/saline			Total area (ha)
	Lake Alexandrina	Lake Albert	Tributary Wetlands	Murray Mouth and Estuary	North Lagoon	South Lagoon	
Marine/coastal wetlands							
Permanent shallow marine waters				X			50
Rocky marine shores	X			X	X	X	788
Sand, shingle or pebble shores	X	X		X	X	X	1,020
Estuarine waters				X			2,200
Intertidal mud, sand and salt flats				X	X	X	3,142
Intertidal marshes				X	X		536
Intertidal forested wetlands				X			4
Coastal brackish/saline lagoons				X	X	X	10,128
Coastal freshwater lagoons				X	X		41
Inland wetlands							
Permanent rivers/stream/ creeks	X		X			X	221
Seasonal/intermittent/ irregular rivers/streams/creeks	X						200
Permanent freshwater lakes	X	X	X				79,480
Seasonal/intermittent freshwater lakes	X						120
Seasonal/intermittent saline/brackish/alkaline lakes and flats	X	X				X	1,729
Seasonal/intermittent saline/ brackish/alkaline marshes/ pools	X	X	X			X	1,289
Permanent freshwater marshes/pools	X	X	X				4,474
Seasonal/intermittent freshwater marshes/pools	X		X				1,037
Shrub-dominated wetlands	X	X				X	4,875

Wetland types found within the Ramsar site	Freshwater			Estuarine/saline			Total area (ha)
	Lake Alexandrina	Lake Albert	Tributary Wetlands	Murray Mouth and Estuary	North Lagoon	South Lagoon	
Freshwater, tree-dominated wetlands	X		X			X	1,470
Freshwater springs; oases						X	<10
Human-made wetlands							
Seasonally flooded agricultural land	X		X				1,235
Water-storage areas			X				1
Canals and drainage channels, ditches	X	X	X				44

(Source: Phillips & Muller 2006)

2.1.3 Lake Albert

Lake Albert supports seven wetland types (Table 2-2). It contains remnant patches of *Gahnia filum* and extensive and highly significant *Phragmites australis* and *Typha domingensis* reedbeds, which provide excellent shelter habitat for a range of fish and other vertebrate species, as well as long-term rookery sites for ibis, spoonbill and cormorants (Phillips & Muller 2006).

2.1.4 Tributary wetlands

The tributary wetlands (Table 2-2) associated with three Eastern Mount Lofty Ranges' streams—Finniss River, Tookayerta Creek and Currency Creek—are nationally significant, supporting dense and diverse wetland flora and significant fauna such as the Mount Lofty Ranges' southern emu wren and pygmy perches (Phillips & Muller 2006). In the recent drought, and as a consequence of the associated record low flow into the lake and low lake levels, much of this fringing habitat was disconnected from the lake shoreline for an extended period. As such, habitat for many species was temporarily lost, and fauna such as the Yarra pygmy perch are now believed to be extinct from the River Murray (Bice 2010), but captive populations are held.

2.1.5 Murray Mouth and Estuary

The Estuary and Murray Mouth provide a diversity of habitats within nine wetland types (Table 2-2).

2.1.6 North and South Coorong Lagoons

The South Lagoon of the Coorong provides a diversity of fauna habitats associated with 10 wetland types, and the North Lagoon provides six wetland types (Table 2-2).

Historically, the submerged annual plant *Ruppia tuberosa* (*R. tuberosa*) dominated the South Lagoon, forming the primary diet of a number of waterbird species and together with other submerged aquatic plants such as *Lamprothamnion* sp. once provided habitat for a variety of species. *R. tuberosa* is a major contributor to primary production to the Coorong ecosystem, driving the system's capacity to support higher organisms, as well as providing physical habitat important for juvenile fish (Phillips & Muller 2006).

Prior to the hypersalinisation of the South Lagoon in the first decade of the 20th century *R. tuberosa* occurred predominantly in the Coorong Southern Lagoon (Phillips & Muller 2006). However, as of early 2009 it was effectively absent from the South Lagoon. This was a consequence of a combination of extended periods of hypersaline conditions and low water levels possibly acting in synergy to deplete seedbanks and cause multiple impacts on the plant's life cycle. In 2009 it appeared to be slowly increasing in distribution and abundance in the North Lagoon (Rogers & Paton 2009). Loss of *R. tuberosa* has resulted in the loss of the associated community from the South Lagoon. Within the systems in which *R. tuberosa* dominates there are no species that have an equivalent role. It has a particular role in ecosystem stability, providing critical habitat and food sources, which form the basis of a low-complexity food web sustaining a diversity of high trophic level organisms (Thompson & Starzomski 2007).

Although not a "keystone species" in the strictest sense (Power et al. 1996), *R. tuberosa* does exert a strong effect on biodiversity (Duffy et al. 2007), by virtue of its large biomass and trophic position, because of the complex microhabitat array it provides for other species, and because of the diversity of waterbirds known or suspected to feed on it.

2.1.7 Key indicators of functioning ecological processes

A suite of indicators are used by Lester et al. (2011a, b) to describe the key ecological processes of the Lower Lakes and Coorong region. The maintenance of these processes, the associated components and ecosystem services, are the foundation of the ecological character of the system and represent the basis for management objectives. These indicators include:

1. Vegetation (including phytoplankton): including 13 vegetation indicator species and assemblages, between them, that covered a range of aquatic vegetation communities from the terrestrial edge of the floodplain to the lower edge of the euphotic zone (see Muller (2010) for further information).
2. Fish: including 17 indicator fish species, between them, that covered the range of freshwater, estuarine and marine habitats across the site, as well as different strategies for using the site (e.g. migratory and resident). Pest species (i.e. common carp *Cyprinus carpio*) were also included as an indicator of decline in site conditions and/or fish communities.
3. Macroinvertebrates: including 19 macroinvertebrate indicator species that were chosen to cover the gradient of freshwater, estuarine, marine and hypersaline habitats within the Coorong, Lower Lakes and Murray Mouth (CLLMM) region. The level of knowledge regarding their functional role within the region varied significantly among species. One of the main limitations in using macroinvertebrates as indicators for this region was the lack of specific knowledge and local data, particularly for the Lower Lakes, so much of the rationale for this group was drawn from research and management that was undertaken.
4. Ecological processes: including 10 key ecological processes that were used to indicate the overall health and productivity of an ecosystem without the need to monitor every species that is present. Ecological processes selected as indicators included basic ecological functions such as photosynthesis, decomposition, nutrient cycling, along with ecological responses to changing environments such as responses to salinity, acid/base and sediment dynamics, water clarity, terrestrialisation (or re-wetting), food-web functionality and functional connectivity. Other ecological processes considered included colonisation (including invasive issues) and bioaccumulation (both of potential pollutants but also carbon sequestration).

Lester et al. (2011a) summarises the identified links between each process and the ecological indicators.

2.2 Ecological management objectives

The CLLMM icon site objectives, as set by the Murray-Darling Basin Ministerial Council (see Lower Lakes, Coorong and Murray Mouth Icon Site Environmental Management Plan 2006–2007 (MDBC 2006)), are:

- An open Murray Mouth.
- Enhanced migratory wader habitat in the Lower Lakes and Coorong.
- More frequent estuarine fish spawning and recruitment.

A series of 17 specific ecological targets have been developed relating to native fish (including freshwater, diadromous and estuarine/marine), freshwater and estuarine vegetation, benthic invertebrates, mudflats, waterbirds, water quality and connectivity to inform progress against these three high-level objectives, as per MDBC (2006).

The objective for the CLLMM region specified by the most-recent draft of the long-term plan for the site is that it continues to be a "healthy, resilient wetland of international importance" (DEH 2010).

The Murray-Darling Basin Authority (MDBA 2010) notes six broad objectives for the CLLMM:

1. To conserve the Ramsar site consistent with its ecological character at the time of listing.
2. To protect and restore ecosystems that support migratory birds listed under international agreements.
3. Protect and conserve natural, or near-natural, rare or unique water-dependent ecosystems (in their current state).
4. To protect and restore water-dependent ecosystems that provide vital habitat.
5. To protect and restore water-dependent ecosystems that support Commonwealth, state or territory-listed threatened species and communities.
6. The asset supports, or is capable of supporting, significant biodiversity.

Each of these objectives is linked to at least one Ramsar criterion.

In order to determine an environmental water requirement for the Lower Lakes and Coorong with explicit links between hydrodynamic and ecological outcomes, Lester et al. (2011a) identified eight ecological objectives necessary to achieve a healthy resilient wetland for the CLLMM region. A detailed rationale for each of these objectives is outlined in Lester et al. (2011a). These ecological objectives are:

1. The region supports a range of species that persist without major and/or ongoing management intervention.
2. A range of species are able to successfully breed and recruit in the region without interruption.
3. Water links the various habitats and management units at the site.
4. A range of habitats exist within the region.
5. A suitable salinity gradient is maintained across the site.
6. Both flows and water levels vary through time.
7. A variety of ecological functions are supported at appropriate levels.
8. Links exist between aquatic and terrestrial ecosystems.

For the purpose of this document, the ecological objectives for targeted water use in each of the main water management areas are outlined below (Table 2-3).

Table 2-3: Ecological objectives for targeted water use

Water management area	Broad-scale system objective	Ecological objectives
Lock 1 to Wellington: main channel, permanent and semi-permanent wetlands and floodplain	Flood peak enhancement.	Promote: • productivity, health and diversity of floodplain vegetation • connection between wetland and riverine aquatic habitats • broader and more productive littoral vegetation • more diverse and productive flood-dependent fauna • temporary seasonal habitats.
Lakes Alexandrina and Albert	Enable export of salt and nutrients from the Murray-Darling Basin through an open Murray Mouth.	Maintain water quality required by salt-sensitive flora and fauna species.
	Variable inter and intra-annual lake level regime.	Promote: • productivity, health and diversity of riparian and floodplain vegetation • connection between fringing wetland and lake aquatic habitats • broader and more productive littoral vegetation • more diverse and productive flood-dependent fauna • annual fauna reproductive events • diverse epiphyte community • temporary seasonal habitats. • Maintain lake levels at sufficient heights to avoid acidification.
	Maintain longitudinal connectivity.	• Allow annual migration of fish between lakes and estuary.
The Coorong and River Murray Estuary	Minimum inter and intra-annual over barrage flow.	Promote: • ongoing estuary-ocean connectivity • productivity, health and diversity of fringing and submerged aquatic vegetation • connection between fringing wetland and lake aquatic habitats • broad and productive estuarine, marine and hypersaline habitats • more diverse and productive flood-dependent fauna • annual fauna reproductive events • temporary seasonal habitats.

3. Watering management objectives

3.1 Asset objectives

3.1.1 Lock 1 and Wellington

Most floodplain wetlands between Lock 1 and Wellington have become permanently wet with little change in water regime. Water levels can increase or decrease by around 0.5 metres on a daily basis through wind seiching, though these fluctuations are typically short periodic fluctuations. Regulators have been installed on some small individual wetlands to enable wetting and drying cycles to be introduced to these wetlands.

Cooling et. al. (2010) describes the inundation of floodplain and floodplain wetlands throughout the South Australian River Murray. The document presents this information according to the river's three key geomorphic stretches; the broad floodplain from the border to Lock 3, the gorge section with the constrained floodplain corridor from Lock 3 to Mannum (located between Lock 1 and Wellington), and the heavily altered floodplains from Mannum to Wellington. In order to discern flow figures for inundation between Lock 1 and Wellington, it was therefore necessary to interpret the figures from both the Lock 3 to Mannum, and Mannum to Wellington sections of the document.

Therefore, from Cooling et. al. (2010) it can be understood that additional wetland areas are inundated at flows exceeding 30,000 ML/day with minimal further increases in inundation once flows exceed 75,000 ML/day. Significant floodplain inundation occurs at flows above 55,000 ML/day, with inundation is largely complete at 100,000 ML/day.

Water management objective: to generate flows within the flow band of 30,000 to 75,000 ML/day, for a duration of between 30 to 90 days, commencing late spring to support inundation of floodplain wetlands and floodplains between Lock 1 and Wellington. Antecedent conditions will determine the frequency with which these flows are generated as both wet and dry years will be required.

Thus, this watering objective aims to achieve two key things—a flow band that will support the inundation of additional floodplain wetland areas, and a flow band that includes volumes large enough to begin significant inundation of the floodplain itself. This objective does not target maximum floodplain inundation, but provides for a significant extent of inundation to occur.

This flow regime should be targeted downstream of Lock 1 to benefit the floodplain through associated increased productivity, health and diversity of floodplain vegetation, improved connection between wetland and riverine aquatic habitats, creation of a broader and more productive littoral vegetation, with the result of a more diverse and productive flood-dependent fauna and maintenance of temporary seasonal habitats.

Where possible benefits can be achieved by adding volumes to existing flows to either increase the peak of smaller flows above the 30,000 ML/day threshold, and/or extend the period over which flows greater than 30,000 ML/day are maintained.

3.1.2 Lakes Alexandrina and Albert

Under natural conditions, water levels in Lake Alexandrina and flows to the sea would have been closely linked to River Murray flows, with substantial seasonal and annual variability (see Muller 2010). Increasing regulation within the MDB has enabled water levels to be held relatively constant for approximately the past 50 years for water extraction, transport and recreational purposes. Historically, the key levels in the Lower Lakes have been: +0.60 mAHD as a preferred minimum level and +0.75 mAHD for full supply level. The surcharge level of +0.85 mAHD is the height at which water begins to spill over the barrage spillways, and at +0.87 mAHD inundation of surrounding land commences.

As a result of this loss of variability in lake levels there has been a simplification of riparian ecosystems and the accumulation of sulfidic soils over time (Lester et al.2011a). To support the ecological requirements of the Lower Lakes, as presented above, and in accord with objectives established by the MDBA, three key water management objectives have been identified and are being proposed for the purpose of this document.

Water-management objectives:

1. **Provide sufficient flows to enable export of salt and nutrients from the Basin through an open Murray Mouth:**
   - **Salt export: 2 million tonnes per year.**
   - **Water quality target: salinity less than 700 µS cm^{-1} at Tailem Bend.**
   - **Barrage flow: Rolling 10-year average greater than 3,200 GL/year.**
2. **Provide a variable lake level regime to support a healthy and diverse riparian vegetation community while maintaining lake levels above 0.0 mAHD to manage acidification issues.**
3. **A minimum flow of 150 ML/day[1] through the existing barrage fishways (J Higham [DENR] 2011, pers. comm.) be provided at all times to promote fish passage between Lake Alexandrina and the River Murray estuary. This volume will need to be increased as more fishways are installed.**

Increased water level variability and improved water quality are key water management objectives for the River Murray below Lock 1 including Lake Alexandrina and Lake Albert (Lester et al. 2011b; MDBA 2010). The identification of a target water level envelope for Lake Alexandrina was largely based on the requirements of vegetation indicator species and assemblages (Muller 2010). These targets are described in Section 4.2.

The salinity target at Tailem Bend is designed to achieve a water quality suitable for raw drinking water, to facilitate extraction for domestic purposes. Lester et al. (2011b) also propose a salinity target of 700 µS cm^{-1} in Lake Alexandrina. This is a conservative target proposed for Lake Alexandrina because of the strong relationship between salinity in Lake Alexandrina and Lake Albert.

1 This is a minimum flow requirement to meet fishway operation at the barrages, with preferred optimum flow rates to include sufficient volumes for supporting multiple objectives, such as the provision of attractant flows for fish, and with consideration of water management objectives for the Coorong and Murray Mouth.

The salinity level in Lake Albert is consistently higher than that of Lake Alexandrina because of evapo-concentration effects which are exacerbated because there is no through flow; water can only enter and leave the lake via the Narrung Narrows which are of relatively limited capacity (Heneker 2010). Inspection of the observed salinity data presented in Heneker (2010) (refer Figure 3-1) highlights that the salinity in Lake Albert rarely falls below 1,000 µS cm^{-1}.

When Lake Alexandrina salinity exceeds 700 µS cm^{-1} it is likely that the salinity in Lake Albert will exceed 1,500 µS cm^{-1}. This salinity threshold is approaching the upper end of the tolerances of some of the identified key aquatic plant species in this system and where sub-lethal effects to a range of fauna species are likely.

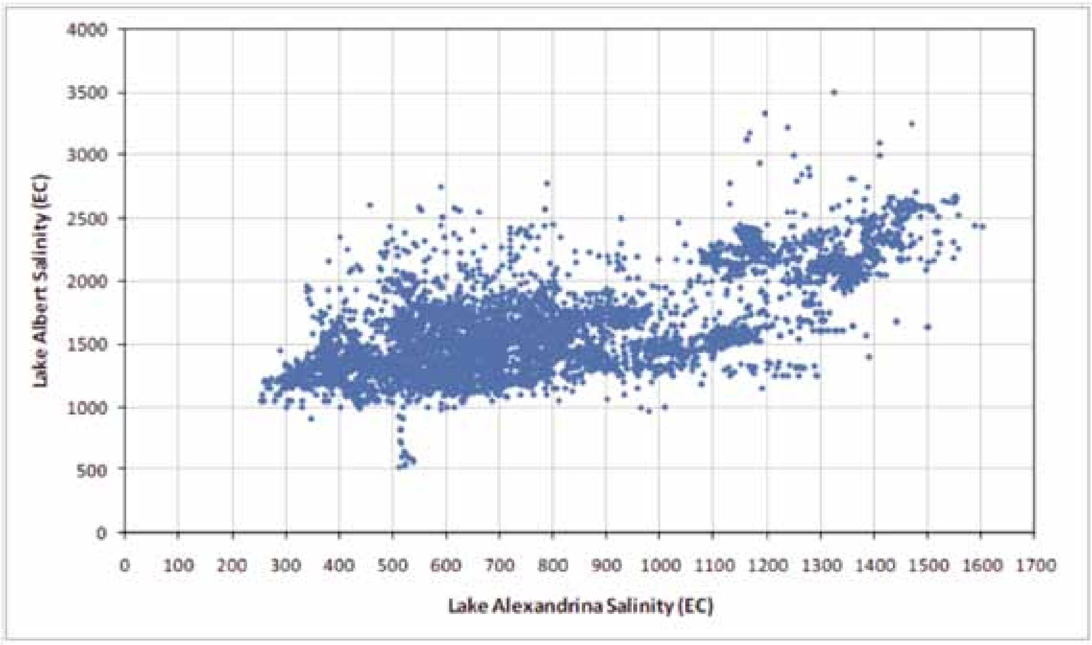

Figure 3-1: Relationship between observed salinity in Lake Alexandria and Lake Albert (pre- April 2007).

(Source: Heneker 2010)

Some data on key habitat species with low salinity tolerances is currently unpublished and subject to current monitoring programs. This information is expected to be published in the near future and this will add to the knowledge of the Lower Lakes' ecosystem. One such species of interest is *Myeariophyllum caput-medusae*, extensive beds of which have been present historically providing core native fish habitat. This species has a low salinity tolerance and has disappeared under recent drought and high lake salinity conditions (J Nicol 2011, pers. comm.).

Thus, 700 µS cm^{-1} is currently considered a reasonable target for lake management, and setting a higher salinity target for Lake Alexandrina would be highly likely to affect the ecological character of Lake Albert.

3.1.3 Murray Estuary

Implicit in the objectives for the South and North Lagoon is the following proposed objective for the Murray Mouth (also identified in MDBA 2010).

Water management objective: provide sufficient flows to enable export of salt and nutrients from the Basin through an open Murray Mouth.

3.1.4 Coorong North Lagoon

To meet the key ecological objectives identified in Section 2, and the broad-scale objectives as identified in MDBA (2010), the following water management objective and associated management targets are proposed.

Water management objective: maintain a range of estuarine, marine and hypersaline conditions in the Coorong, to support healthy populations of 'keystone' species such as *Ruppia megacarpa* in the North Lagoon.

The targeted characteristics for Northern Lagoon salinity required to achieve this objective are:

a. **Average annual salinity less than 20 g/L (35,700 µS cm^{-1}) in a proportion of years.**

b. **Maximum salinity less than 50 g/L (89,000 µS cm^{-1}).**

3.1.5 Coorong South Lagoon

To meet the key ecological objectives identified in Section 2, and the broad-scale objectives as identified in MDBA (2010), the following water management objective and associated management targets are proposed.

Water management objective: maintain a range of estuarine, marine and hypersaline conditions in the Coorong, to support healthy populations of 'keystone' species such as *Ruppia tuberosa* in the South Lagoon.

The targeted characteristics for Southern Lagoon salinity required to achieve this objective are:

- **Average long-term salinity less than 60 g/L (107,000 µS cm^{-1})**
- **Maximum salinity less than 100 g/L (179,000 µS cm^{-1}) in 95 per cent of years**
- **Maximum salinity less than 130 g/L (232,000 µS cm^{-1}) in 100 per cent of years**.

Water level is also understood to be an important consideration for ecological health in the South Lagoon. However, water level objectives are yet to be established and require further investigation.

4. Environmental Water Requirements

A substantial body of knowledge exists on the ecology of the CLLMM region. This has been collected over many years by a variety of researchers and government agencies (see Department of Environment and Planning 1990; Sloan 2005; Ferguson 2006a,b,c,d; Phillips & Muller 2006; Ferguson, Ward & Geddes 2008; Jennings et al. 2008; Bice & Ye 2009; Brookes et al. 2009; Noell et al. 2009; and Bice 2010).

In addition, literature reviews summarising information on the ecology of the region have recently been compiled as a part of the development of the *Securing the Future: a long-term plan for the Coorong, Lower Lakes and Murray Mouth* (the Long-Term Plan) (e.g. Fluin et al. 2009; Aldridge et al. 2010; Bice 2010; Ecological Associates 2010; Gehrig & Nicol 2010; Napier 2010; Shiel 2010; Rolston et al. 2010) and external to that process Lester et al. (2008).

This recent work on the Long-Term Plan has been the culmination of investigation work associated with the CLLMM Murray Futures project and represents more than four years of research and investigations. It has formed the technical basis for much of this environmental water use document.

4.1 Main Channel Lock and Weir 1 to Wellington

Flow Volumes

As mentioned in Section 3, most wetlands along this stretch of the river are permanently inundated with a small additional area inundated by flows exceeding 30,000 ML/day and minimal additional increases once flows exceed 75,000 ML/day.

On the floodplain along the main river channel between Lock 1 and Wellington, significant floodplain inundation does not commence until flows exceed 55,000 ML/day and is largely complete at a discharge of 100,000 ML/day (Ecological Associates 2010a). The total area of inundation across watercourses, wetlands and floodplains in this reach of the River Murray is shown by Figure 4-1.

The main flow band where change in inundation area occurs for floodplain wetlands is between 30,000 ML/day and 75,000 ML/day. Hence, increased inundation could be achieved where the opportunity arises to augment small natural floods to increase flows once they are going to exceed 30,000 ML/day. The required volume would be flood specific, but typically would require additional flows of 5,000 to 10,000 ML/day for one to three months in late spring. By targeting flows in this flow band above 55,000 ML/day, environmental watering would also ensure that significant floodplain inundation commences.

There is relatively little floodplain vegetation remaining and little to distinguish the flow thresholds of the vegetation types. The 115 hectares of remnant river red gum forest is largely inundated by flows between 40,000 and 60,000 ML/day, but river red gum woodland, samphire, lignum shrublands and black box woodlands are all gradually inundated between flows of 50,000 and 90,000 ML/day (Ecological Associates 2010a).

There are regulators on some small individual wetlands within this part of the system that can be operated to allow drying of these wetlands and control of wetting/drying cycles. Other than introducing regulated drying and refilling cycles (back to pool level) there are only limited opportunities to manipulate water levels other than through flow augmentation. The majority of wetlands throughout this reach of the river do not have management plans that describe individual site water management regimes.

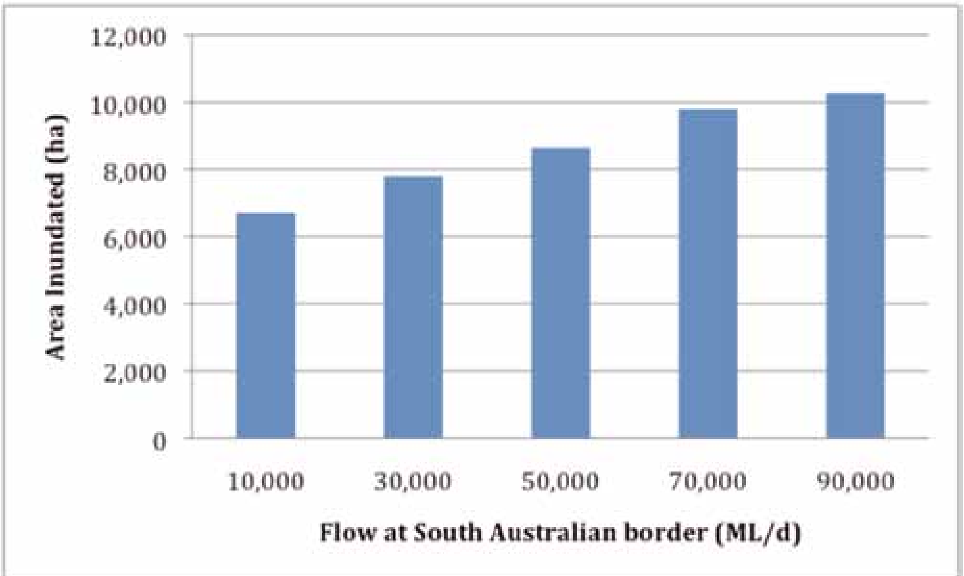

Figure 4-1: Inundation of watercourses, wetlands and associated floodplains with increasing flow from Lock 1 to Wellington.

(Source: DFW Floodplain Inundation Model)

4.2 Lakes Alexandrina and Albert

Flow volumes and salinity targets

The majority of recommendations regarding environmental flows for the Lower Lakes focus on a two or three-year return interval (Jensen et al. 2000). This is partly due to the relatively short 'memory' (i.e. the length of time in which the influence of a large flow is apparent) both for the Lower Lakes and the Coorong, but also partly due to the unregulated nature and thus limited control that can be exerted over high flow events (Lester et al. 2011).

Large flows have the ability to lower the salinity of the system for up to three years, after which they would begin to rise again. Thus, rules were developed (Heneker 2010, Lester et al. 2011b) to specify the minimum volume of water needed to pass over the barrages (thus commencing the flushing of salt from Lake Alexandrina) over a three-year period.

Flows sufficient to achieve the long-term average annual salinity of 700 µS cm^{-1} in Lake Alexandrina should be the target for most years (Lester et al. 2011b); requiring flows in excess of the minimum requirement. A maximum salinity of 1,000 µS cm^{-1} in Lake Alexandrina should be maintained in 95 per cent of years, and never exceeding 1,500 µS cm^{-1}.

Heneker (2010) determined that to meet the more conservative target of 700 µS cm^{-1} in Lake Alexandrina—which represents a high degree of certainty for maintaining the Ramsar site's ecological character—flows over the barrages in any given year should be the maximum of:

1. 3,150 gigalitres
2. 8,000 gigalitres—F_{X-1} or
3. 12,000 gigalitres—F_{X-1} – $F_{X-2.}$

   where F_{X-2} is equal to the lesser of the actual outflow two years prior to the current year and 4,000 gigalitres, and where F_{X-1} is the flow volume from the previous year.

In dry years (up to 5 per cent of the time) where the 700 µS cm^{-1} target cannot be met, in order to meet the salinity target of a maximum of 1,000 µS cm^{-1} in Lake Alexandrina, flows over the barrages in any given year should be the maximum of:

1. 650 gigalitres
2. 4,000 gigalitres—F_{X-1}, or
3. 6,000 gigalitres—F_{X-1} - $F_{X-2.}$

   where F_{X-2} is equal to the lesser of the actual outflow two years prior to the current year and 2,000 gigalitres, and where F_{X-1} is the flow volume from the previous year.

Modelling was undertaken to determine if the above targets could be met by existing management arrangements and water allocations. For the salinity targets in Lake Alexandrina of 1,000 and 700 µS cm^{-1}, additional average flows of 1,427 and 2,622 gigalitres were required for 44 and 78 out of 117 years respectively (Lester et al. 2011b). This identifies that in nearly half of all modelled years the 1,000 µS cm^{-1} could not be achieved without additional flows.

Further, Heneker (in Lester et al. 2011b) determined that additional flow volumes of 850 GL/year were required to ensure that the absolute maximum (sub-lethal) annual salinity level of 1,500 µS cm^{-1} in Lake Alexandrina was not exceeded. This additional flow was required in 25 out of 117 years. The recommended annual maximum of 1,500 µS cm^{-1} for Lake Alexandrina should be thought of as an absolute maximum, to be avoided wherever possible in order to maintain a healthy ecosystem. This salinity figure does not replace the desired salinity target of 700 µS cm^{-1} in Lake Alexandrina but rather is designed to provide guidance for operators for periods when flow and salinity targets cannot be met for what the system can tolerate for short periods.

Should lower flow volumes be delivered, it is unlikely that healthy marine or hypersaline ecosystems would become established, in the Lower Lakes in particular. This is because low water levels and large fluctuations in salinity mean conditions are likely to be regularly outside the tolerance limits of the associated biota. Thus the fluctuations, and the rate at which these changes occur, are likely to be problematic.

The implications of delivering less water than has been recommended were demonstrated under predicted median and dry future climate conditions for Lakes Alexandrina and Albert, and for the Coorong. Salinities were predicted to rise dramatically in both lakes and in the two lagoons of the Coorong (Lester et al. 2011b).

4.2.5.1 Lake level variability

Increased variability was identified by Lester et al. (2011b) as a key requirement for developing a target water level envelope for the Lower Lakes and river below Lock 1.

The pattern of elevating and lowering lake levels is driven by the seasonal requirements of the ecology in and around the Lower Lakes. Generally speaking, gradual drawdown over summer and autumn months aims to expose mudflats and support diverse vegetation. Maintaining the lake at a minimum water level is designed to promote diverse littoral and riparian vegetation diversity and support biogeochemical cycling. Gradual winter–spring refilling of the lake supports growth of new vegetation shoots while ensuring fauna have access to vegetation for food, shelter and recruitment. Water levels are kept high during spring to ensure fauna access to habitat (Lester, Fairweather & Higham 2011a).

Target ranges for water levels in Lake Alexandrina on an annual return interval (ARI) of 1 (i.e. water levels to be achieved each year; Figure 4-2) and also at an ARI of 3 (i.e. levels to be achieved every three years on average, which are over and above those levels specified with the ARI of 1; refer to Figure 4-3) have been determined. The water levels that have been specified are monthly averages across the site. Topography and wind seiching mean that there will be significant variability in water levels across the lake and at shorter temporal scales (e.g. daily).

The target temporal water level envelopes identified by Lester et al. (2011a, b) are based on the requirements of vegetation indicator species and assemblages around Lake Alexandrina (Muller 2010; see Lester et al. 2011a). Lester et al. (2011a) offer further explanation on the ecological benefits from seasonal lake level variation for both ARI scenarios.

For the water level envelope with an ARI of 1, lower limits for these water levels have been set with disconnection points within the region in mind (e.g. Hindmarsh Island streams), as well as seasonal requirements for water and connectivity (e.g. fish passage through the Coorong to coincide with migration events). The upper limit for the ARI of 1 water level envelope was determined based on the water requirements of the riparian zone and its position relative to the floodplain. Differences between the water level envelopes for ARI's of 1 and 3 are largely focused on achieving occasional flooding of the surrounding floodplains. For detailed information regarding the seasonality of the lake level envelopes, including detailed information on minimum and maximum lake levels, see Lester et al. (2011a).

An understanding of other environmental management issues that exist outside of these lake envelopes is also critical. These include the intrusion of saline groundwater, and the exposure of acid sulphate soils at, and below, 0.0 mAHD (see Section 1.3.3). Concerns around lowering lake levels to such a point that risks the ability to fill the lake to within its target envelope in the subsequent year are also present. This concern plays a role in influencing the minimum lake level of +0.35 mAHD specified in the ARI 1 envelope (Lester et al. 2011a). These management issues will also play a role in managing lake level variability.

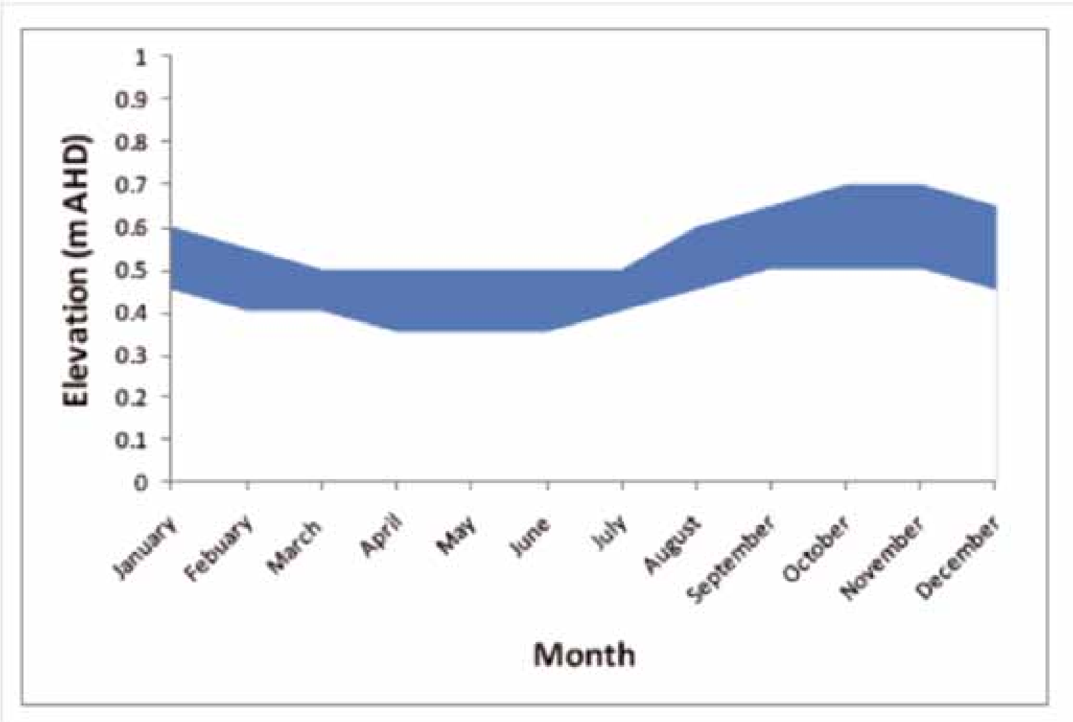

Figure 4-2: Proposed target envelope for water level in Lake Alexandrina at an ARI of one year showing upper and lower limits.

(Adapted from Muller 2010, in Lester et al. 2011b)

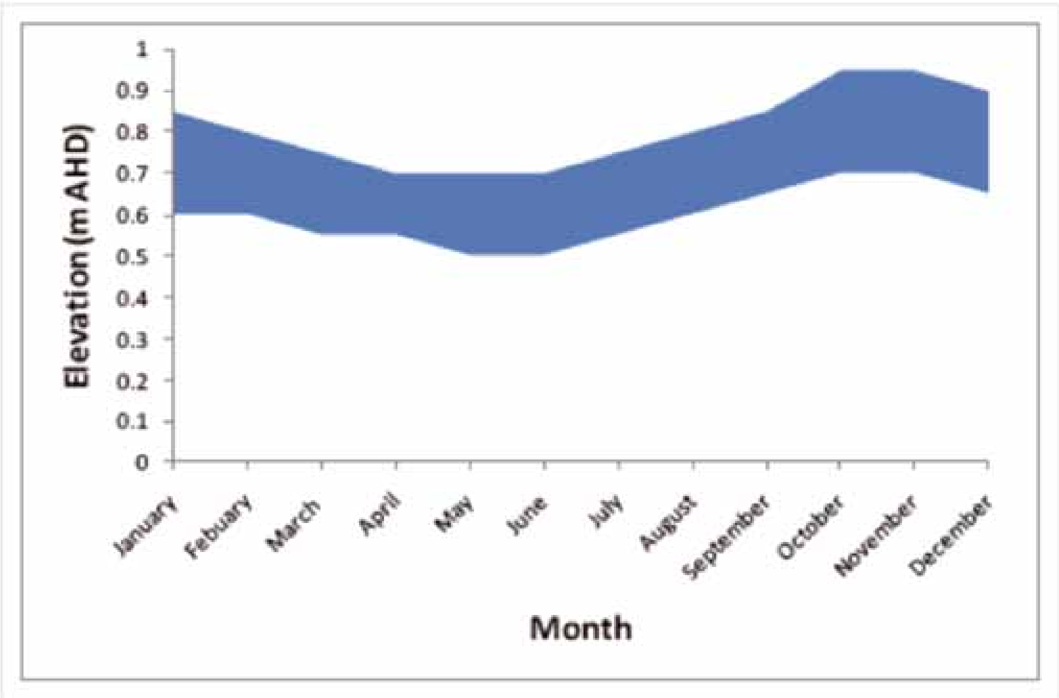

Figure 4-3: Proposed target envelope for water level in Lake Alexandrina at an ARI of three years showing upper and lower limits.

(Adapted from Muller 2010 in Lester et al. 2011b)

Lake level management is key to wetting and drying fringing wetlands of the Lower Lakes. However, several wetlands in this region can be hydrologically managed via the use of existing flow-control structures. These wetlands include Narrung wetland, Waltowa swamp and Tolderol wetland.

Maintaining the water level of the Lower Lakes within the target envelope of seasonal variability has only a minor implication for water allocation. Under the historical water level management regime for the benchmark scenario (1995 level of development assuming historical climate), the monthly variability in losses from the Lower Lakes was high, with the average ranging from less than 1 gigalitre in June to around 140 gigalitres in December and January. Analysis of the lake bathymetry data indicates that the surface area of the Lower Lakes varies by only approximately 3 per cent over the normal water level range of +0.4 to +0.9 mAHD (refer to Appendix 1), indicating that seasonal variation in loss was driven by climate (mainly evaporation) seasonality, not variation in lake surface area. Most of the time the water level in the lakes is controlled by barrage operation rather than River Murray inflows, although lake levels will fall if inflows are insufficient to offset losses (including releases).

Compared with the benchmark scenario, the proposed lake level target regime produces overall lower lake levels. This regime would produce a lower volume of losses than under benchmark conditions, however the difference would be small.

4.2.5.2 Barrage flow volumes

A key further consideration for the management of the Lower Lakes is to ensure there are sufficient flows though the barrages to promote connectivity between the lakes, ocean and Coorong.

Construction of the barrages caused a barrier to fish migration. Fish movement from the lakes to the Coorong remained possible when the barrage gates were open, but movement in the reverse direction was restricted due to the high flow velocities and physical structure of the gates. Such movement is particularly important for diadromous and migratory species that require access to both marine and freshwater habitats to complete their life cycles. Since 2002, five fishways have been constructed to facilitate fish passage. Minimum flow requirements at the barrages for the purpose of maintaining broader fish passage targeting diadromous fish species is estimated to be 150 ML/day which equates to 55 gigalitres over a full water year (J Higham (DENR) 2011, pers. comm.).

Similarly, flows through the barrages to establish estuarine conditions within Boundary Creek and downstream of Goolwa barrage, as well as provide attractant flows for Goolwa fishway, total a minimum of 164 GL/year. Further attractant flows (at Tauwitchere and Goolwa) total 202 GL/year (DFW 2010).

The minimum flow requirements for maintaining fishways are outlined in Table 4-1.

Table 4-1: Minimum barrage flow requirements to meet the needs of diadromous and migratory fish speciees.

Month	Barrage flows (GL)			
	Fishways	Maintain connectivity with estuary	Attractant flows	Total
Jan	4.7	18.6	37.2	60.5
Feb	4.2	16.8		21.0
Mar	4.7	18.6		23.3
Apr	4.5			4.5
May	4.7			4.7
Jun	4.5			4.5
Jul	4.7	18.6		23.3
Aug	4.7	18.6	18.6	41.9
Sep	4.5	18	36	58.5
Oct	4.7	18.6	37.2	60.5
Nov	4.5	18	36	58.5
Dec	4.7	18.6	37.2	60.5
Year	**55**	**164**	**202**	**421**

(Source: DFW 2010)

4.3 Coorong North and South Lagoons and Murray Estuary

The water requirements are largely driven by managing water salinity to acceptable tolerance levels. Water level is also thought to be a driver for ecosystem health but there is currently insufficient information to effectively describe the water requirements. The systems' requirements are further complicated by the long lag and influences associated with antecedent conditions. For example, an average South Lagoon salinity of greater than 117 g/L (209,000 µS cm^{-1}) has been shown through modelling to be the best predictor of degraded ecosystem states three years in advance (Lester et al. 2011a).

A key requirement is the exchange of water between the sea, the River Murray and the Coorong. These exchanges are primarily driven by wind, seasonal and diurnal tidal variations and flow through the barrages.

Barrage flows from Lake Alexandrina influence the salinity dynamics in the Coorong in at least three important ways (Webster 2007):

- Periods of elevated barrage flows deepen the mouth channel, which in turn allows more active mixing along the length of the Coorong.
- By freshening the water at the northern end of the North Lagoon (relative to seawater) the water with a lower salinity flows along the Coorong to replace evaporative losses further along the system. Even after evaporation increases the salt concentrations in the two lagoons, a lower salinity is maintained.
- When there are flows through the barrages, the water level in the whole system tends to increase and water is pushed along the Coorong. Generally, variations in discharge cause the water level in the Coorong to rise and fall causing back and forth water exchange along the system, which enhances longitudinal mixing.

Sea level variations with periods of elevated water level longer than a few days penetrate into the Coorong more effectively than shorter period fluctuations and can be important drivers of water level fluctuations in both lagoons. Penetration increases as the period increases, as the mouth channel deepens, and increases with higher sea levels.

Coorong hydrodynamics are best correlated with barrage flows at a one-year lag (Lester et al. 2011a). Barrage flows from more than two years prior to the year in question have little impact on the predicted mix of ecosystem states. This is likely to be due to the role of the Murray Mouth in regulating hydrodynamics within the Coorong. Mouth depth influences the transmissivity of water between the Coorong and Encounter Bay, and is primarily a function of barrage flows in the current year (Lester et al. 2011b). Long-term effects of high flow events are not seen, as the majority of fresh water passes through the mouth, and seasonal siltation processes do not allow a deep mouth to persist through time.

Research (Webster 2007, Lester et al. 2011b) has demonstrated that the health of the Coorong is sensitive to closure of the Murray Mouth and it is very unlikely that the Coorong would support predominantly healthy ecosystem states without functional connectivity to the mouth. For barrage flows less than 1,225 GL/year, modelling suggests there is a high likelihood that the entire Coorong will fall into degraded ecosystem states, with more than 6,000 GL/year required to minimise the likelihood of more than 50 per cent of sites in degraded ecosystem states (Lester et al. 2011a).

Management of flows to achieve a healthy state in the Coorong is complex, requiring an iterative approach. Conditions in the preceding years markedly alter the best case scenarios needed to manage flows into the system. Where a nominal volume of water is available, long drawn out releases over autumn or spring achieve a markedly better ecological outcome than a single short flow high volume pulse (Webster et al. 2009).

Notwithstanding this, for the Coorong and Murray Estuary specifically, the following minimum flow requirements over the barrages have been suggested (Lester et al. 2011a):

- There should be no years in which no flow passes over the barrages. The absolute minimum barrage flow should be between 50 GL/year and 120 GL/year (this meets the minimum requirement for maintaining fishways, however, is unlikely to prevent salinity thresholds being exceeded).
- Over any two-year period, at least 600 GL/year should be released to the Coorong to prevent South Lagoon salinity thresholds of 117 g/L (209,000 µS cm^{-1}) to be exceeded.
- At least 2,500 gigalitres over two years as a minimum target (95 per cent of the time) to prevent extreme salinity levels occurring in the South or North Lagoons which would result in the decline in key species such as *Ruppia tuberosa* and small-mouthed hardyhead (*Atherinosoma micrstoma*) fish species.

High flows of 6,000 and 10,000 GL/year should be maintained at a frequency of every three and seven years over the barrages into the Coorong.

Ideally a minimum daily flow regime to reduce the risk of mouth closure is required which has been estimated to be 2,000 ML/day (Close 2002). For the purpose of modelling a daily flow rate of 3,000 ML/day was adopted as a conservative estimate for this document, but it is anticipated this will be updated with a seasonal distribution once a seasonal distribution has been established with confidence.

If the requirements for Lake Alexandria can be met this will also achieve the desired outcomes for the Coorong North and South Lagoons and the Murray Estuary.

4.4 Modelling used to establish requirements for the Lower Lakes and Coorong

Modelling was undertaken by Heneker (2010) and Lester et al. (2011b) to determine the environmental flow requirement for the CLLMM region. The modelling was used to develop environmental water requirements for the Lower Lakes based on ecological first principles (Lester et al. 2011b).

Lester et al. (2011b) described eight ecological objectives (see section 2.1.2) and 33 ecological outcomes that are associated with healthy and resilient wetlands. These objectives are in line with the South Australian Department of Environment and Natural Resources (DENR) stated goal that the region be maintained as a healthy, resilient wetland of international importance.

Lester et al. (2011a) compiled a comprehensive list of species, assemblages and ecological processes that would occur in the CLLMM region under the ecological character described for the Ramsar site (Phillips & Muller 2006). This list was then linked to the ecological objectives and outcomes, and their flow-related requirements (including water quality, water level, connectivity and return intervals for flooding and barrage flows) were assessed from the literature.

In turn, the ecological objectives and outcomes were linked to a suite of indicators specific to the CLLMM region in order to assess ecological condition locally (Muller 2010). Where species and assemblages were selected as indicators, these focused on those that could be considered: keystone species or assemblages in the region; 'canary' species or assemblages (i.e. sensitive species that are likely to be early indicators of change); or threatened species or assemblages as matters of national environmental significance (as defined by the *Environment Protection and Biodiversity Conservation Act 1999* (Cwlth)).

Hydrodynamic modelling

The effect of environmental water allocations on the hydrodynamics of the Coorong was investigated using a one-dimensional hydrodynamic model (Webster 2007). This model simulates water levels and salinities along the length of the Coorong, allowing the effect of varying barrage flows to be assessed and compared between scenarios.

The model simulates water movement and levels along the entire domain, as these respond to the driving forces associated with water-level variations in Encounter Bay (including tidal, weather band, and seasonal), winds, barrage inflows, flows in Salt Creek (USED), and evaporation (Lester et al. 2011b). The model simulates the broad response of the system in both salinity and in water level, explaining approximately 90 per cent of salinity changes in the system (Lester et al. 2011b).

The hydrodynamic model was run for 19 scenarios. The scenarios contained combinations of flows to support different salinity targets in Lake Alexandrina, in combination with different climate change scenarios. Current water allocations were modelled under an historical climate, plus median and dry future climate scenarios, as was natural flow (i.e. with no extractions in the Murray-Darling Basin) under historical climate conditions (Lester et al. 2011b).

Ecosystem response modelling

In order to assess ecological condition in the Coorong, Lester et al. (2011b) used an existing ecosystem response model based on "ecosystem states" (Webster et al. 2009). Using the response model the likely mix of ecosystem states in the Coorong that would be supported by the flow regimes designed to meet salinity targets in Lake Alexandrina were identified (Lester et al. 2011a, b).

The ecosystem states model is a statistical model, where data for the region have been statistically analysed and modelled to identify associations and relationships between the biota that occur within the system at any one point in time, and the environmental conditions under which they occur (Lester et al. 2011b). The ecosystem state model developed for the Coorong identified eight distinct ecosystem states. These can be divided into two 'basins of attraction': a marine basin and a hypersaline basin. Within each basin, there are four states, ranging from a healthy state to a degraded state. Thus, the four states within each basin are considered to be a continuum of conditions from a healthy ecosystem to a more-degraded ecosystem, although it should be noted that a diverse range of conditions is the norm for the Coorong region.

The critical thresholds of each of the indicator species and processes were identified, where possible, for water quality; flow regime; connectivity; and water levels (including links to water quality and connectivity) (see Lester et al. 2011a for information).

Lester et al. (2011a) then directly related the identified indicators of ecological condition to the hydrodynamics and flow regime of the Lower Lakes and Coorong and explicit trade-offs were explored regarding the effect of different values of each parameter. Based on this process, and the historical condition of Lake Alexandrina and other similar freshwater lakes, targets were set for use in hydrological modelling in the lakes.

Hydrological modelling

Hydrological modelling used the historical flow record from the River Murray and existing models for the Lower Lakes and Coorong to explore the various flow regimes and likelihood of meeting the desired targets. Flow sequences required to maintain the salinity targets, and thus water levels, were also explored.

Outputs from the hydrological modelling were then used to assess the ecological implications of the recommended flow regime for the ecology of the CLLMM region. This assessment was qualitative for the Lakes. This modelling was used to develop rules for the minimum delivery of water to the Lakes.

Based on the hydrodynamic requirements, as well as the predicted flows required to support ecosystem states in the Coorong, several possible salinity targets for Lake Alexandrina were identified. Salinity was the variable that required the most flow to support in the long term (thus, if flows were sufficient to meet the salinity targets for Lake Alexandrina, other targets such as those associated with water levels should also be met). Three qualitative targets for salinity in Lake Alexandrina were explored: an annual mean of 700 µS cm^{-1}; an annual maximum of 1,000 µS cm^{-1}; and an annual maximum of 1,500 µS cm^{-1}. Flow sequences into Lake Alexandrina were explored to develop rules for additional flow to maintain salinities below the threshold levels in Lake Alexandrina and to achieve water level and/or flow requirements for the suite of indicators.

Annual flow bands

Four bands of annual flow at the barrages have been identified as part of developing this environmental water use document that relate to specific ecological thresholds (Table 4-2). For specific seasonality of flows, refer to Section 4.2 Figure 4-2, Figure 4-3 and Table 4-1. These flow bands all put achieving target lake levels as a first priority which then by default achieves the targets for fringing wetlands and other freshwater components of the Lower Lakes' ecosystem. The flow bands are presented to guide manager responses in any one particular year, however, it is recognised that antecedent conditions are significant and there are long lag times (two to three years).

Table 4-2: Bands of forecast annual flow at the barrages for July to June water year with suggested management responses to meet ecological objectives.

Total flow requirements over the barrages for water year (July-June)	Management response	Ecological objectives	Frequency of implementation of response
0 to 60 GL/year	• Boost flows to at least 60 GL/year. • Further boost flow as required to achieve salinity target. • Manipulate water level of lakes to achieve target regime. • Prioritise flows through fishways.	• Maintain connectivity between the lakes and the estuary. • Achieve salinity lower than or equal to 1,500 µS cm^{-1}. • Achieve water level variability of lakes to maintain health of riparian vegetation.	Annually.
60 to 650 GL/year	• Boost flows to at least 650 GL/year. • Further boost flow as required to achieve salinity target.	• Achieve the minimum flow required to avoid unrecoverable degradation of ecological health, including stimulating fish recruitment through flows for fishways, attractant flows, and maintaining connectivity between the lakes and the estuary. • Achieve a lake salinity lower than or equal to 1,000 µS cm^{-1}. • Maintain functional connectivity at the mouth in the majority of years.	Meet in at least 95 per cent of years, with non-complying years non-sequential.
650 to 2,000 GL/year	• Boost flows to at least 1,000 GL/year (to ensure 1,500 µS cm^{-1} threshold is not exceeded. • Further boost flow as required to achieve salinity target (<1,000 µS cm^{-1}).	• Additionally, achieve an enhanced degree of openness of the Murray Mouth. • Enhanced spring fresh to increase certainty of stimulating fish recruitment. • Additionally, achieve a salinity annual mean of ≤1,000 µS cm^{-1}	Meet mouth maintenance target in at least 90 per cent of months. Meet full spring fresh target in 90 per cent of years.
>2,000 GL/year	Boost flows as required to achieve salinity targets in Lake Alexandrina and Coorong South Lagoon.	• Additionally, achieve a salinity annual mean of ≤700 µS cm^{-1} to prevent degradation of marine states in the Coorong and achieve a high degree of certainty that the Ramsar-nominated ecological character will be maintained.	Maintain as the long-term average (meet in at least 50 per cent of years).
	• Periodically boost flows to at least 6,000 GL/year.	• Additionally, achieve a healthy hypersaline state in the South Lagoon.	Maintain long-term average frequency of every 3.6 years, and maximum interval of 5 years.
	• Periodically boost flows to at least 10,000 GL/year.	• Additionally, achieve a healthy hypersaline state in the South Lagoon.	Maintain long-term average frequency of every 10.4 years, and maximum interval of 17 years.

Note: The objectives of each flow band in table 4-2 are additional to those of the lesser flow band/s.

Summary of justification for the flow bands

The steady state annual flow that will sustain less than 1,500 µS cm^{-1} in Lake Alexandrina is 1,000 gigalitres. However, annual flows less than this (down to 60 gigalitres) are tolerable for individual years provided the flows in the two previous years are sufficient, such that salinity remains less than 1,500 µS cm^{-1}. Hence there is a need to review flow delivery over a three-year rolling average.

The steady state annual flow that will sustain less than 1,000 µS cm^{-1} is 2,000 gigalitres. When annual flows regularly exceed 2,000 gigalitres, available additional water can be used to reduce salinity towards the target of 700 (annual mean). The long-term average salinity target for the Lower Lakes is 700 µS cm^{-1} (Lester et al. 2011a), which would be approximated by achieving an annual mean salinity of 700 µS cm^{-1} in 50 per cent of years.

By providing sufficient steady baseflow over the barrages each month, the flow in the river would tip the balance in the Murray Mouth to a net outward flow that would assist in preventing sediment entering the inlet during a rising tide, and assist in flushing sediment during an ebb tide (Walker 2002). There is an increasing relationship between flow volumes and the relative openness of the mouth (i.e. more flow means that the mouth will be more open). Functional connectivity at the mouth will be maintained in the majority of years by delivering the flows that achieve salinity lower than or equal to 1,000 µS cm^{-1} in the Lower Lakes (Lester et al. 2011a).

Close (2002) modelled the impact on risk of mouth closure of maintaining low flows over the barrages of 2,000 ML/day. It was estimated that providing this baseflow would reduce the frequency of risk of mouth closure to about 6 per cent of years, compared to the benchmark scenario with 31.5 per cent of years (Close 2002). Thus, improved connectivity can be achieved with baseflows of 2,000 ML/day. Target frequencies for these objectives have not been specified in the literature. Logically, the average frequency of year-round low risk of mouth closure occurring jointly with a high certainty of stimulating fish recruitment (through a spring fresh), should fall between that of achieving the 1,000 µS cm^{-1} target (95 per cent of years) and the 700 µS cm^{-1} target (50 per cent of years).

A healthy hypersaline state in the South Lagoon requires regular flows of 6,000 GL/year and 10,000 GL/year (Lester et al. 2011a). According to Lester et al. (2011a), these flows should continue to be exceeded at the long-term average frequencies characteristic of the benchmark scenario, which they calculated to be every three and seven years respectively. The modelling undertaken for this project utilised a MSM-Bigmod TLM scenario extending from July 1895 to June 2009 and all calculations were based on water years. In this scenario, annual flows exceeding 6,000 gigalitres and 10,000 gigalitres occurred at long-term average frequencies of every 3.6 and 10.4 years respectively, so the long-term targets used herein have been reset to these frequencies.

The application of the above water requirements targets for water delivery is discussed further in Section 5.

5. Operating regimes

The supply of water to the region below Lock 1 under a regulated flow regime requires a release(s) to be made from upstream storages, either from storages on the River Murray (e.g. Hume Dam) or from the Darling (e.g. Menindee Lakes) systems. The flow to South Australia can be further manipulated (to a degree) by the control of releases from Lake Victoria. The flow to South Australia is set in the field by officers of SA Water based at Berri, South Australia, acting under the direction of River Murray Operations (RMO).

Flow into South Australia is measured under two scenarios determined at Gauging Station (GS) 426200 on the River Murray downstream of Rufus River. If the river height at Gauging Station 426200 is:

- Less than 5.80 metres then flow to South Australia equals flow at GS 426200 + flow at Mullaroo Creek Offtake – Lindsay River allowance.
- Greater than 5.80 metres then flow to South Australia equals flow at GS 426200.

Lake Victoria is the last storage to provide opportunities to manage or manipulate flows in any significant way upstream of Lake Alexandrina. Lock weir pools can be adjusted to influence water levels but the storage volumes they provide are relatively small and hence any flow adjustments they provide are short lived.

Water levels in Lake Alexandrina and the flow through the barrages can be controlled by any of the five sets of barrages. The distribution of flow across the barrages can have an impact on mixing in the North Lagoon of the Coorong and hence any releases require monitoring and adjustment to avoid unwanted results. In general, releases are spread across the Tauwitchere and Goolwa barrages; these releases are managed in part to preserve navigation channels for boats and prevent the lateral movement of the Murray Mouth. The bathymetry of the system is highly variable and hence an adaptive management approach must be applied throughout each release sequence.

Minimum lake-level targets are based on the requirements of vegetation indicator species and assemblages around Lake Alexandrina, while considering disconnection points and seasonal connectivity requirements. However, other management issues do play a role in influencing minimum lake levels (see Section 4.2 for further information).

The proposed approach relies on forecasting flows over a 12-month period. This period is appropriate given that the ecology of the Lower Lakes (and Coorong) is heavily influenced by antecedent conditions over a one to two year time frame. System health is influenced by the conditions that prevailed one or two years previous (Lester et al. 2011b) and system response is influenced by long term (yearly rather than monthly or weekly time periods). Hence any planning decisions need to be made in recognition of past conditions and a long-term forecasting approach is required.

MDBA and DFW presently prepare long-term monthly flow forecasts for planning purposes for lake levels. These forecasts are based on modelled flows to South Australia and this information can be used to provide estimates of flow over the barrages for different inflow regimes.

5.1 Decision triggers for initiating water delivery

Decision triggers have been outlined below in a series of examples designed for longer term implementation of targeted flow regimes (however, these can be equally applied for the short term once a flow forecast is determined).

Water delivery priorities have been assigned based on advice from DENR (J Higham 2010, pers. comm.), with regard to the work of Lester et al. (2011b), and with regard to the draft Icon Site Management Plan. Priorities for meeting the water management objectives have been established because the work underpinning for this document, including Lester et al. (2011b), has highlighted that in many years the full range of desired watering objectives cannot be met.

Achieving minimum lake level targets is considered of highest priority (as explained in the previous section) followed by ensuring variable levels to provide fringing wetlands and lake ecosystems with the desired seasonal water regime.

Once the lake level objective has been achieved, consideration should first be given to achieving the water quality targets (which are based on supporting the ecological objectives of the Lower Lakes) because if these targets can be met then it is likely that the remaining flow based ecological targets can also be achieved. Maintaining sufficient barrage flows to achieve the salinity targets will therefore also ensure that there is sufficient water for the fishways.

The proposed hierarchy for water delivery is as follows:

1. Maintain seasonal water levels in Lake Alexandrina within target levels.
2. Maintain salinity levels in Lake Alexandrina below target levels.
    a. 700 µS cm^{-1} or, if this is not possible,
    b. below 1,000 µS cm^{-1} or, if this is not possible,
    c. below 1,500 µS cm^{-1}.
3. Maintain minimum flow (1,090 GL/year) over the barrages to keep an open Murray Mouth.
4. Manage fishways:
    a. maintain flow through fishways, plus, if there is sufficient water availability,
    b. maintain connectivity of fresh water flows to the River Murray estuary
    c. provide attractant flows, plus, if there is sufficient water availability
    d. provide spring pulse flows through the barrages to support breeding/recruitment.

    Note: Managing flows through the fishways will be a higher priority in years of low flow, where maintaining connectivity will be the primary aim of environmental watering. However, in years of higher flows, it is expected that targeting flows to achieve water quality objectives will also ensure sufficient flows for the fishways.
5. Allow additional flows through the barrages to facilitate the export of salt from the river system and achieve a healthy hypersaline state in the South Lagoon of the Coorong.

5.2 Capacity to meet ecological objectives for different flow regimes and water availability

The hierarchy outlined above was applied to a range of flow series scenarios. The flow scenarios were all provided by MDBA and included the:

- natural flow scenario (assumes no water resources development)
- benchmark scenario ((BM) assumes 1995 level of water resources development)
- benchmark plus The Living Murray water scenario (BM + TLM) (assumes 1995 level of water resources development and within assumed allocation constraints (i) attempting to meet an ecologically desirable target range of lake water levels and (ii) providing 2,000 ML/day (2,500 ML/day in October to December) over the barrages for maintaining the Murray Mouth in an open state).

The modelling process and results are presented in full in Appendix 1.

Analysis of the frequency with which the ecological objectives were met under the benchmark scenario plus allowance for TLM water indicates there is a significant shortfall in many years between the desired flow over the barrages and that which is available.

As expected, the natural flow scenario showed a high level of compliance with the ecological targets, meeting the salinity needs within the desired long-term frequencies (Table 5-1). The other ecological needs were met in 96 per cent of months, but because the non-complying months were scattered throughout the record, only 74 per cent of years had full compliance with other ecological needs (Table 5-1).

The benchmark scenario had low compliance with ecological targets, failing on all required long-term frequencies for salinity targets, and achieving the targets for other needs in only 9 per cent of years (Table 5-1). The Living Murray allocation (BM + TLM) led to a significant improvement in achievement of other ecological needs, rising to 44 per cent of year targets achieved (Table 5-1). The improvement in achievement of salinity targets was less dramatic. This is because the main objective of the TLM environmental water is to maintain the mouth in an open state.

A scenario was run assuming that there was no constraint on water availability. For this scenario only the rules for achieving the 6,000 and 10,000 GL/year targets were adjusted to achieve the desirable long-term average frequency and no better than the maximum frequency (without this adjustment the frequencies would have been higher than necessary to meet the targets). This scenario revealed the volume of water required in each year to augment the flow with the objective of fully complying with all ecological targets. However, there are some aspects of this scenario that deem it impractical:

- In 22 per cent of years the required water exceeds 1,500 gigalitres, and in 9 per cent of years it exceeds 4,000 gigalitres—these volumes are high compared to the volumes that are likely to be available through environmental water allocations.
- In 19 per cent of years, flow at the barrages has to be more than doubled to achieve the targets.
- In general, larger volumes of environmental water are required in years of lower flow at the barrages. In reality, the availability of environmental water is likely to be lower in such years, dependent on the volumes of carryover from the previous water year.

The other scenarios assumed that the availability of environmental water was constrained (Table 5-1). These are hypothetical scenarios, intended only to illustrate the trade-off between water availability and achievement of ecological health targets. Given the unlikeliness of unconstrained allocations being available, it will not be possible to meet all of the ecological targets all of the time, so it is inevitable that some of the time the health of the CLLMM asset will be affected. Having an effective process for balancing water availability and ecological health will be fundamental to the management of the CLLMM asset.

In the scenarios tested, the targets for specific flow based ecological needs were easier to achieve than the salinity targets. An annual allocation of 500 gigalitres or more, with no carryover, achieved the less than 2,000 GL/year targets in 99 per cent of years. Carryover was of variable importance; it was instrumental in improving compliance with targets for other needs if the annual allocation was low, and it was important in improving compliance with salinity targets if the annual allocation was large (Table 5-1). Success in meeting the 6,000 and 10,000 GL/year targets principally depended on the arbitrary additional volume of environmental water provided for this purpose.

Illustration of how potential supply of allocated environmental water holdings could be distributed to augment the flow under the constrained allocation scenarios is provided for two scenarios: 300 gigalitres with no carryover (up to 300 gigalitres in storage) (Appendix 1, Figure 0-4) and 800 GL/year with carryover permitted (up to 3,000 gigalitres in storage) (Appendix 1, Figure 0-6). These scenarios illustrate how environmental water is required in years of low to moderate flow, which is the fundamental management problem of the CLLMM asset.

Health indicator scores were determined for the modelled scenarios. These scores were calculated as the observed annual flow divided by the annual flow required to fully meet the targets (observed to expected (O/E) scores). The CLLMM asset health indicator scores (Appendix 1, Figure 0-8 and Figure 0-9) were favourable for the entire time series of the natural scenario, except for 2006 to 2008, when the 700 µS cm^{-1} salinity target was rated very poor. In the benchmark scenario there were periods of high compliance with ecological targets, but overall, the health indicator scores were poor most of the time. The period of worst health was from 2002 to 2008.

Comparing three of the environmental water availability scenarios:

- A scenario with 300 gigalitres annual allocation and no facility for carryover satisfied the other objectives, but the 700 µS cm^{-1} and 1,000 µS cm^{-1} targets were only partially met in most years.
- A scenario with 800 gigalitres of annually allocated environmental water and up to 3,000 gigalitres being held in storage almost satisfied all of the targets; the 700 µS cm^{-1} target was met in approximately half of the years (as desired), and in the non-complying years the health score for this indicator was mostly in the range poor to very poor (O/E score of 0.2 to 0.6).
- A scenario with unlimited allocation available satisfied all of the targets. Note that for good ecological health the 700 µS cm^{-1} target does not have to be met in every year, as the requirement is for this to be the long-term average salinity. This is the main difference in health achieved by this scenario compared to that of the natural scenario. Although having unlimited allocation available achieved all of the ecological targets, the performance of this scenario was only marginally better than the scenario with allocation constrained to 800 gigalitres per year and carryover available, but at an average annual cost of 268 gigalitres per year in additional water.

Table 5-1: Compliance of flow scenarios with ecological targets and environmental water allocation use.

(BM = Benchmark; TLM = The Living Murray; CEW = Commonwealth environmental water, XXX/YYYY (XXX = annual allocation, YYYY = max allocation that can be held in storage)

Scenario	Salinity targets			Other ecological needs						Other ecological needs combined (for Q < 2,000 GL)		CEW allocation used		
	0 – 60 GL	60 – 650 GL	>650 GL	0 – 60 GL	60 – 650 GL	650 – 2,000 GL		> 2,000 GL						
	1,500 EC % of years met	1,000 EC % of years met	700 EC % of years met	% of years met	% of years met	Mouth open % of mths met	Spring fresh % of years met	6,000 GL max. interval (years)	10,000 GL max. interval (years)	% of mths met	% of years met	% of years called on	Mean (±SD) (GL/ year)	Max. (GL/ year)
Target	100	95	50	100	95	90	90	5 years	17 years	-	-	-	-	-
Natural	100	98	94	100	100	96	96	3	5	96	74	-	-	-
BM	82	63	31	95	88	51	50	11	22	49	8	-	-	-
BM + TLM	89	71	32	97	92	92	46	11	21	86	42	-	-	-
BM + TLM + CEW 200/200	93	75	38	100	92	93	78	7	14	93	68	74	373 (629)	2,888
BM + TLM + CEW 200/1000	94	76	40	100	95	93	84	7	14	94	76	73	425 (702)	3,664
BM + TLM + CEW 200/2000	94	76	42	100	95	93	85	7	14	94	77	73	428 (702)	3,664
BM + TLM + CEW 300/300	96	77	39	100	96	93	91	7	14	96	83	74	417 (619)	2,888
BM + TLM + CEW 300/1000	96	78	44	100	97	93	94	7	14	97	88	73	502 (745)	3,664
BM + TLM + CEW 300/2000	96	78	45	100	97	93	95	7	14	97	89	73	503 (746)	3,664
BM + TLM + CEW 500/500	97	80	39	100	100	96	100	6	14	100	99	73	505 (659)	3,016
BM + TLM + CEW 500/1000	98	80	46	100	100	96	100	5	14	100	99	71	623 (829)	3,664
BM + TLM + CEW 500/2000	98	81	49	100	100	96	100	5	14	100	99	71	643 (840)	3,664
BM + TLM + CEW 800/800	98	82	43	100	100	96	100	6	14	100	100	72	625 (739)	3,475
BM + TLM + CEW 800/1000	98	85	46	100	100	96	100	5	14	100	100	71	709 (875)	3,664
BM + TLM + CEW 800/2000	98	88	50	100	100	96	100	5	14	100	100	71	775 (951)	3,800
BM + TLM + CEW 800/3000	100	92	51	100	100	96	100	5	14	100	100	71	815 (1014)	3,930
BM + TLM + CEW unlimited	100	98	65	100	100	96	100	5	17	100	100	67	1,078 (1713)	8,384

Note: Green shading = target met; red shading = target not met.

5.3 Water allocation and supply decision support

As outlined in Section 4 and above, the targets for flow and salinity all vary depending on antecedent conditions over the previous two years as well as flows during the forecast year. Furthermore, the capacity to achieve the targets is limited by the available environmental water during the current year, including any provisions for carrying over water.

The process for predicting likely environmental water requirements is proposed as follows:

1. Assess the flow forecast for the coming year, consider also:
    a. a lower bound estimate (entitlement flow)
    b. dry scenario (30th percentile monthly flows)
    c. median scenario (50th percentile monthly flows)
    d. wet scenario (assumed to be 70th percentile monthly flows).

    This can be done by forecasting flow to South Australia for the year and then running this through MSM-Bigmod (incorporating provision for TLM water).

2. Calculate the annual flow target forecast for the 700 and 1,000 μS cm^{-1} salinity targets. This includes consideration of flows of previous years.
3. Forecast the environmental water availability for the year, including any carryover.
4. Compare the annual forecast and forecast ranges (dry, wet etc.) including the available environmental water with the target annual flow for the year to determine if that target can be met. If the desired target cannot be met then adopt the highest flow regime target that can be achieved.
5. Run MSM-Bigmod model (incorporating provision for TLM water) through the forecast year to determine if minimum lake level targets will be met and calculate the month and amount of any shortfall.
6. Make provision for meeting the shortfall in lake level (volume) in the monthly distribution of the year's available environmental water.
7. Forecast the required monthly provision of environmental water (once water level requirements are satisfied) based on Table 5-2 and re-run MSM-Bigmod (incorporating provision for TLM water) by applying the proposed environmental water distribution to confirm water level and flow targets are met. Adjust as appropriate.
8. Review each month by updating actual flow data and incorporating revised forecasts as they become available.

Table 5-2: Target flow regime monthly distribution (volumes).

Month	Flow (GL)							
Jul	5	52	93	148	263	348	548	948
Aug	5	52	93	192	330	432	672	1,152
Sep	5	59	90	259	443	579	899	1,539
Oct	5	60	93	285	492	645	1,005	1,725
Nov	5	59	90	259	443	579	899	1,539
Dec	5	60	93	210	348	450	690	1,170
Jan	5	60	93	185	300	385	585	985
Feb	5	46	84	96	1,65	216	336	576
Mar	5	51	93	93	93	93	93	93
Apr	5	50	90	90	90	90	90	90
May	5	51	93	93	93	93	93	93
Jun	5	50	90	90	90	90	90	90
Annual Target	60	650	1,095	2,000	3,150	4,000	6,000	10,000

Table 5-3: Target flow regime monthly distribution (percentages).

Month	Flow Proportion (%)							
Jul	8%	8%	8%	7%	8%	9%	9%	9%
Aug	8%	8%	8%	10%	10%	11%	11%	12%
Sep	8%	9%	8%	13%	14%	14%	15%	15%
Oct	8%	9%	8%	14%	16%	16%	17%	17%
Nov	8%	9%	8%	13%	14%	14%	15%	15%
Dec	8%	9%	8%	11%	11%	11%	12%	12%
Jan	8%	9%	8%	9%	10%	10%	10%	10%
Feb	8%	7%	8%	5%	5%	5%	6%	6%
Mar	8%	8%	8%	5%	3%	2%	2%	1%
Apr	8%	8%	8%	5%	3%	2%	2%	1%
May	8%	8%	8%	5%	3%	2%	2%	1%
Jun	8%	8%	8%	5%	3%	2%	2%	1%
Annual target (GL)	60	650	1,095	2,000	3,150	4,000	6,000	10,000

The flow distribution for target annual flows of 1,095 gigalitres or less are based entirely on criteria described in Table 4-1 and the requirement to maintain a minimum barrage flow of 3,000 ML/day to maintain an open Murray Mouth. In flow years where the achievable flow is above 1,095 gigalitres, the first 1,095 gigalitres is apportioned in accordance with the above requirements with the balance apportioned throughout the year in accordance with the distribution presented in Table 5-4.

Table 5-4: Proposed flow distribution for flows over 1,095 GL/year.

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
10%	6%	0	0	0	0	10%	12%	16%	18%	16%	12%

The distribution in Table 5-4 is based on the 'natural' flow to South Australia regime reported in Heneker (2010) but adjusted so that the flow over the barrages for the mid-range cases (i.e. between 2,000 GL/year and 4,000 GL/year is similar to the natural flow condition).

The resultant monthly flow sequences for the annual flows presented in Table 5-2 are illustrated in Figure 5-1. The distribution is uniform for the low flow years when only the primary aim is to ensure flow through the fishways and connectivity is maintained between the Lower Lakes and the Coorong. As more water becomes available the proposed approach biases water delivery to the late spring-early summer period in line with the 'natural' flow regime. The mid-flow ranges most closely match the natural flow regimes.

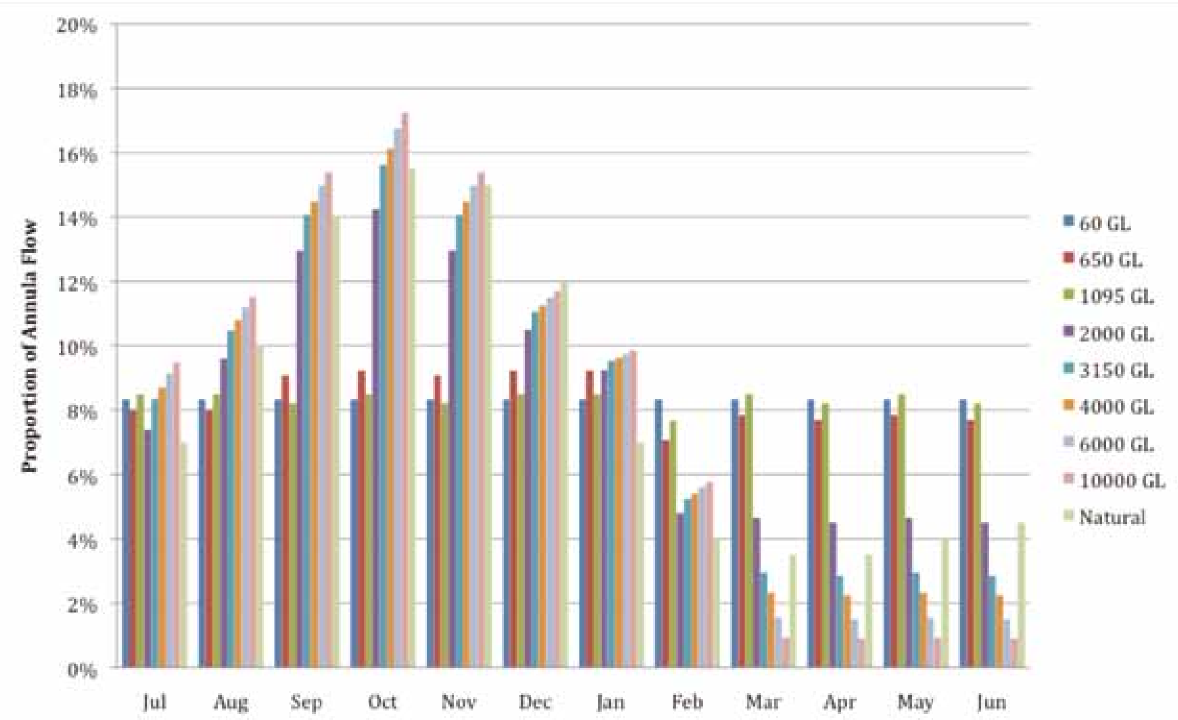

Figure 5-1: Distribution of flow over barrages from proposed watering plan flow allocation for a range of annual flows (as listed in Table 5-2).

As previously discussed, the proposed approach relies on 12-month forecasts. Table 5-5 provides a series of monthly flow sequences based on the MDBA benchmark flow series. These could be used as a starting point in the absence of other forecasting tools in the short term.

Table 5-5: Designated monthly flow bands for flow over the barrages to support interim flow forecasts (GL)*.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Extreme Dry	0	0	0	0	0	0	0	0	0	0	0	0
30th percentile	62	56	62	60	62	60	62	116	199	155	75	62
50th percentile	62	57	62	60	62	107	165	399	490	524	168	79
70th percentile	66	83	132	118	166	298	491	818	964	1,013	723	413

* Note: Percentiles are based on monthly percentiles not annual percentiles

Appendix 2 includes several case studies that illustrate this proposed approach.

5.4 Proposed water-delivery infrastructure

Water delivery would be achieved using existing infrastructure.

Environmental water for the CLLMM is likely to be delivered from Hume Dam, Menindee Lakes and Lake Victoria. To a lesser extent, tributary flows originating in the northern Victorian rivers and the Murrumbidgee River may also contribute. Given the position of the CLLMM at the end of the Murray-Darling system, environmental watering of the asset may be part of a broader multiple-site environmental watering process.

Depending on the desired environmental flow outcome for the CLLMM, there are a number of options for how the water could be delivered. An example delivery option may involve a release of environmental water from Hume Dam as part of managed watering of an upstream environmental asset. Water not used by the upstream sites (i.e. system return flows) would be passed down to the South Australian border, either as a trade or passing flow. The delivery of traded environmental water to South Australia would be the responsibility of the lower River Murray river operator, SA Water. It is likely that part of the environmental water would also be used to water sites upstream of Lock 1, which could include the operation of regulators and weir pool manipulations.

5.5 Water-delivery accounting

Environmental water delivered to South Australia is accurately accounted for at the South Australian border.

There is a velocity index rating gauging station at the town of Morgan that that could be used for water delivery accounting and there are also staged index rating stations at Overland Corner and Lyearup. All of the locks can estimate flow, however, this is more accurate at lower flows, and so flow information through these structures are estimates only. Flow is not measured at the barrages, instead it is estimated based on a rate of 300 ML/day per gate/bay (500 ML/day at Mundoo). However, flows can be significantly less when water levels are elevated in the North Lagoon. Annual barrage flows are determined by assessing the water balance calculation. When flows are less than 50,000 ML/day, the estimates of flow past Lock 1 is considered to be more reliable than the estimates for flows over the barrages. At these flow rates the weir panels at Lock 1 are still in place, whereas at higher flows the weir panels are removed and the lock is 'drowned out'. Ultimately, it is likely that large multiple-site water deliveries will need to be accounted for using a combination of site measurement, hydrological modelling and net loss calculations.

5.6 Operational constraints

The suggested volumes of water can be delivered utilising existing infrastructure and operating regimes.

River channel capacities are generally not a constraint to delivering the recommended flows. The thresholds for significant flooding that would involve significant water loss generally exceed 50,000 ML/day, which is substantially more than regulated flow conditions.

Lake levels in Lake Alexandrina and Lake Albert need to be maintained above +0.35 mAHD to avoid the risk of activating acid sulphate soils with a factor of safety of between 100 to 200 millimetres. This, and the requirements to maintain seasonal variations in lake levels, limits the extent to which these two lakes can be used to provide a balancing storage.

A number of boating regattas are carried out in the summer months in the Lower Lakes. Maintenance of lake levels above +0.35 mAHD is also required to facilitate navigation which would be achieved by maintenance of the minimum target water levels.

6. Governance and planning arrangements

6.1 Strategic delivery partners

The principle delivery partners in involved water to assets within the Coorong, Lower Lakes and main channel below Lock 1 are:

- South Australian Department for Water
- South Australian Department of Environment and Natural Resources
- South Australian Murray-Darling Basin Natural Resources Management Board
- Murray-Darling Basin Authority (River Murray Operations)
- SA Water.

South Australian Department for Water

The South Australian Department for Water (DFW) is the primary authority for the delivery of environmental water in South Australia.

Broadly, the DFW is responsible for water policy, the issuance of water licences and the management of water allocation in South Australia. The Environmental Water Management Team in the DFW is responsible for managing environmental water against Class 9 entitlements (see Section 8.1.4), directing operation of managed pool-level wetlands and coordinating other watering activities in the South Australian Murray. The team is also responsible for developing environmental watering proposals and coordinates input from other agencies, the South Australian Murray-Darling Basin Natural Resources Management Board and local environmental groups.

DFW has joint management of the Lower Lakes, Coorong and Murray Estuary due to its role in The Living Murray icon site management. The South Australian Department of Environment and Natural Resources (DENR) also manage aspects of the site. Both agencies coordinate primarily through a number of committees set up to govern the Lower Lakes and Coorong Recovery Murray Futures project.[2]

South Australian Department of Environment and Natural Resources

The South Australian Department of Environment and Natural Resources (DENR) is responsible for the *National Parks and Wildlife Act 1972* (SA) and manages national parks. The Coorong, Lower Lakes and Murray Mouth group within DENR manages the Lower Lakes and the Coorong Murray Futures project. DENR manages wetlands that are located on crown land and national parks (including areas of the CLLMM).

2 Under the Australian Government's *Water for the Future* program up to $200 million will be provided to the CLLMM, which is managed under the state's Murray Futures initiatives.

South Australian Murray-Darling Basin Natural Resources Management Board

The South Australian Murray-Darling Basin Natural Resources Management Board (the Board) is responsible for land and water management on the South Australian Murray. The Board works collaboratively with community groups, Local Action Planning committees and land owners on wetland management (e.g. undertaking works, preparing management plans and monitoring). The Board serves this function from Chowilla Game Reserve through to the Lower Lakes, excluding areas that are managed by DENR (which includes crown land and national parks).

Murray-Darling Basin Authority—River Murray Operations

The Murray-Darling Basin Authority (MDBA) owns barrage and lock infrastructure in South Australia and is responsible for directing their operation.

The supply of environmental water to the CLLMM would likely require a water allocation transfer from interstate to South Australia. River operators will need to be consulted to ensure that the water can be delivered in the required timeframe, and infrastructure can be operated as required.

The MDBA also coordinates the Barrages Operations Advisory Group which advises on the direction of barrage releases. This group includes representatives from MDBA River Murray Operations, DFW, DENR, SA Water and the DSEWPaC. On occasion it may include ecologists from the South Australian Research and Development Institute (SARDI) to provide additional advice on ecological benefits of barrage releases.

SA Water

SA Water is responsible for operating barrage and lock infrastructure in South Australia, as directed by the MDBA.

6.2 Approvals, licences, legal requirements, other administrative issues

Water use approvals

The Australian Government has no Water Resource Works Approvals or Site Use Approvals to enable use of environmental water in South Australia. Thus, for the Australian Government to use environmental water in South Australia, water allocations are traded to an account that has these approvals. These approvals could be obtained through an application process with landholders' consent, or arrangements could be made to utilise existing approvals held by landholders. The current process includes the development of watering options in consultation with the DFW Environmental Water Management Team and utilisation of the South Australian Minister for Water's environmental water account (which has the required approvals).

Relevant trading rules and system accounting

The supply of environmental water to the assets below Lock 1 would likely require a water allocation transfer from interstate. This water holding would be delivered under the operational arrangements that are established with River Murray Operations, in accordance with trading and delivery protocols outlined in the Murray-Darling Basin Agreement (Schedule 1 to the *Water Act 2007* (Cwlth)).

Paragraph 3 of the Murray-Darling Basin Agreement Protocol 2010 (Schedule D—Adjusting Valley Accounts and State Transfer Accounts) prescribes how traded water allocations are delivered between states. Allocations traded to South Australia must be delivered between September and April in a manner that conserves the proportions of the entitlement pattern, however, the MDBA may deliver outside of the entitlement pattern to match expected demands. This exception provides flexibility to enable the delivery of environmental water to the South Australian border when it is required (in the absence of other delivery constraints).

Trades to South Australia are accounted for at the border by the MDBA. This is the primary, accurate accounting point in South Australia and thus water cannot be ordered to a point downstream of the border.

During periods of surplus flow to South Australia (unregulated conditions), water trades to South Australia are first met by the surplus flows. This is a likely constraint to the use of environmental water holdings, as trading water to South Australia during these conditions would not result in additional water in the system. The trade of environmental water to South Australia would be met by the surplus water already in the system, and not by water held in storages. Other ways of releasing water from storages that would result in increased flows at the South Australian border will need to be investigated to overcome this constraint. A possible solution is the use of return flows from upstream watering actions and tributary flows.

Transferability of water holdings

The Australian Government holds Class 1 and Class 3a entitlements in South Australia. Allocations to both these classes can be traded to another person, intra or interstate.

Other approvals

The current approach to use of environmental water in South Australia has been to engage the Environmental Water Management Team of the DFW to implement water delivery. In this role the DFW has been responsible for ensuring that any approvals required for the watering actions are obtained, including for water delivery, works required to enable that delivery, and any environmental approvals.

6.3 Existing water use planning

6.3.1 Environmental water use plans

Coorong and Lower Lakes

Currently there is no dedicated environmental water allocation plan for the Coorong, Lower Lakes and Murray Mouth; however a TLM icon site environmental water management plan is under development. There have been various studies to estimate the environmental requirements of this site to inform the TLM program and planning for the Murray-Darling Basin Plan (MDBA 2010).

River channel and pool-level wetlands below Lock 1

The majority of wetlands below Lock 1 do not have environmental management plans. The pool-level regulated wetlands approved for Class 9 entitlement do have management plans. Other relevant plans include:

- The River Murray Channel icon site environmental management plan 2006–2007 (MDBC 2006). This plan sets out objectives and management actions to protect and enhance the values of River Murray Channel icon sites, along with a monitoring and evaluation program. An environmental water management plan is currently (2011) being developed for this icon site which will describe more explicitly the environmental water requirements.
- The Water Allocation Plan (WAP) for the River Murray Prescribed Watercourse (South Australian Murray-Darling Basin Natural Resources Management Board, July 2009). The WAP specifies that 200 gigalitres is provided for the evaporative losses for pool-level wetlands and provides guidance on the requirements for pool-level managed wetlands to receive allocation (Class 9 entitlements). Details on how water should be used at the pool-level managed wetlands are described in each approved wetland's management plan.

6.3.2 Other water management plans relevant to environmental water use and planning in South Australia

- River Murray System Annual Operating Plan: this annual plan describes the potential delivery volumes and anticipated operation of major infrastructure along the river for the next water year, taking into account forecasted water availability, constraints such as construction works, objectives for the environment and public water supply.
- The South Australian Strategic River Murray Environmental Water Plan 2008–2013 sets out the principles that guide decision-making by the South Australian Government about environmental water priorities in the South Australian Murray (Stribley & Goode 2008).

7. Risk assessment and mitigation strategies

The risk assessment outlined in Table 7-1 provides an indication of the risks posed to the environmental assets in the Coorong, Lower Lakes and main channel below Lock 1 by the water use options proposed in this document. This table specifically does not include operational risks associated with the delivery of environmental water to the focus area (i.e. it does not include any risks to areas upstream of Lock 1). 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. A framework for assessing risks has been developed by DSEWPaC and is included at Appendix 6.

Table 7-1: Risks associated with environmental water options for the Coorong, Lower Lakes and main channel below Lock

Risk	Description	Likelihood	Consequence	Risk ranking	Mitigation
Water quality and salinity					
Acid sulphate soils (ASS)	ASS are known to occur in Lake Alexandrina and Lake Albert as well as upstream in the Murray channel and associated wetlands (Fitzpatrick et al. 2008a, 2008b, 2009). Any unforseen reduction in flow exposing these soils would present water quality management issues for these areas.	Possible	Moderate	Medium	Undertake a detailed assessment of sites suspected/known to contain ASS to quantify the level of risk and identify appropriate management strategies. If water levels are maintained within the levels proposed in this document, ASS are unlikely to constitute a major risk.
Blackwater (low dissolved oxygen)	Blackwater events in the Murray River generally originate in the upper catchment areas (i.e. central Murray floodplain forests), however, they have the potential to occur anywhere that organic material is mobilised from the floodplain. Blackwater events upstream may carry anoxic waters through to South Australia, and impact local ecology, or, they may be created in South Australia itself.	Unlikely	Moderate	Low	Assess likelihood of high flow volumes creating blackwater events in South Australia and adopt appropriate management strategies for high flow events (e.g. conduct watering outside of the spring-summer period where possible, ensure follow-up flows to the event will occur to flush any anoxic waters). Work with upstream environmental water managers to ensure South Australia is notified of backwater events and develop management strategies to cope with such an event (e.g. ensure follow-up flows to the event will occur to flush any anoxic waters). Blackwater events are likely to be diluted by the time flows reach the South Australian border.
Salt mobilisation during high flows	Salt discharge into the River Murray in South Australia originates from direct groundwater discharge and the mobilisation of accumulated salts in wetlands and from floodplain soils. The risk of salt mobilisation increases with the extent and duration of floodplain inundation. Saline flows may also originate from floodplain inundation occurring upstream of South Australia. Salinity is an ongoing management issue for the Lower Lakes and Coorong, as the receiving water bodies of River Murray flows.	Possible	Major	High	Monitor salinity of flows upstream, and within, South Australia. Ensure appropriate management strategies are in place to manage salt mobilised during and after high river flows (e.g. ensure follow-up flows to the event will occur to flush salts from the river system, and manage lake levels and barrage operations to enable flushing to occur).

Risk	Description	Likelihood	Consequence	Risk ranking	Mitigation
Ecology					
Spread of, or benefit to, non-native vegetation species.	Non-native vegetation species may be spread through the provision of flows.	Possible	Moderate	Medium	Vegetation condition and composition is monitored bi-annually and appropriate management should be instigated should a threat occur. The status and management guidelines for weeds of national significance can be found at: http://www.weeds.gov.au/weeds/lists/index.html. Aquatic weeds likely to occur in the region are listed at: http://www.weeds.org.au/cgi-bin/weedident.cgi?tpl=form.tpl&state=sa&s=&region=sesa&form=water
Spread of, or benefit to, non-native fish species	Environmental water that targets ecological events such as fish spawning and recruitment may also provide benefits to non-native fish species.	Possible	Moderate	Medium	Where possible, the delivery of environmental water should be timed to avoid spawning periods for non-native fish. Allowing connected wetlands between Lock 1 and Wellington to dry could allow removal of carp.
Species impacted by inappropriate flooding regimes	If the environmental flows are interrupted, resulting in a rapid recession/draw-down of river flows then fish may become stranded in off-channel habitats. Also, environmental flows that are inappropriately timed/suddenly stopped may result in a 'false start' to spawning and recruitment processes.	Unlikely	Minor	Low	Environmental watering should be managed to ensure that flows can be provided for the duration required.
Geomorphic impacts					
Erosion	Areas of unstable bank along the North Lagoon could be destabilised by the release of additional flows that could exacerbate these processes by elevating water levels.	Possible	Minor	Low	Monitor areas and if necessary implement bank protection measures before undertaking subsequent releases.
	Areas of unstable bank along the lakes and main river channel could be destabilised by elevating or lowering water levels.	Possible	Minor	Low	Monitor areas and if necessary implement bank protection measures before undertaking subsequent lake level rises. Adjust rates of rise and fall as necessary.
Sedimentation	Increase in sediment transport causing movement in the Murray Mouth and disturbance of navigation channels.	Unlikely	Minor	Low	Considered unlikely at flow rates proposed.

Risk	Description	Likelihood	Consequence	Risk ranking	Mitigation
Hydrology					
Inundation risks	Inundation of semi-permanent wetlands in the area below Lock 1 is likely (to some extent) during the watering actions proposed.	Likely	Minor	Medium	Inundation of semi-permanent wetlands below Lock 1 is targeted as part of the watering actions proposed in this document. Risks to private land or infrastructure, including public inconvenience, should be determined prior to implementation and managed accordingly (including communicating with the landholders and public).
Operational					
Diversionary loss	Landholders may deliberately or inadvertently divert the environmental water for their own personal use.	Unlikely	Minor	Low	Provision of environmental water under regulated river conditions will protect the security of the water from unintentional diversion as it flows from the point of release to the South Australian border. From the border, South Australia will manage water as an environmental flow and it will not be available for consumptive use or capture.
Other risks					
Community perception and reaction	Adverse community reaction to releases of water.	Possible	Minor	Low	Liaise with relevant stakeholders, including SA MDB NRM Board and CLLMM Community Reference Group. Communicate the objectives and benefits of environmental watering through media releases.

8. Environmental water reserves

8.1 South Australian water availability

8.1.1 South Australian entitlement flow

Water availability for the River Murray in South Australia is determined by the Murray-Darling Basin Cap (for South Australia) and the entitlement flow, both prescribed under the Murray-Darling Basin Agreement (Schedule 1 to the *Water Act 2007* (Cwlth)).

The Cap volume determines the volume of water that can be diverted from the River Murray for consumptive purposes (i.e. all other consumptive uses other than the environment). The entitlement flow for South Australia under the Murray-Darling Basin Agreement determines the minimum flows that South Australia will receive across the border.

Under the Murray-Darling Basin (MDB) water sharing rules, South Australia is guaranteed a minimum entitlement flow of 1,850 GL/year. This comprises a consumptive water entitlement of 1,154 GL/year and a dilution and loss entitlement of 696 GL/year (58 gigalitres per month), as summarised in Table 8-1. During periods of low flow, these figures may need to be adjusted by the formal processes outlined in the Murray-Darling Basin Agreement.

Table 8-1: South Australian entitlement flow.

Month	Consumptive share (GL)	Dilution and loss share (GL)	Total entitlement (GL)
July	50.5	58	108.5
August	66	58	124
September	77	58	135
October	112.5	58	170.5
November	122	58	180
December	159	58	217
January	159	58	217
February	136	58	194
March	128	58	186
April	77	58	135
May	35	58	93
June	32	58	90
Annual	**1,154**	**696**	**1,850**

The Murray-Darling Basin Agreement states that if the MDBA decides that flow or prospective flow in the River Murray downstream of its junction with the Great Darling River Anabranch for the month will be in excess of: (a) South Australia's entitlement flow; (b) flows that are required for Lake Victoria; and (c) any use by New South Wales and Victoria downstream of the junction, then surplus (also known as unregulated) flows may occur at the South Australian border. If South Australia receives surplus flow in one month, then it will not alter the entitlement flow for subsequent months.

South Australia's dilution and loss entitlement is fixed and does not match real-time loss and dilution requirements between the border and the Murray Mouth, which typically varies between 950 and 1,350 GL/year. Unregulated flows typically cover any loss and dilution shortfalls in the lower River Murray, and some of the consumptive share may also contribute to meeting these losses. However, during dry periods there is often not enough flow to meet the shortfall (DEH 2010). For example, from March 2007 to September 2010 there was no flow through the barrages as there was not enough water to meet the losses in the system, resulting in water levels in the Lower Lakes reaching record lows.

8.1.2 Additional dilution flow

Since 1989, South Australia has also received additional dilution flows (ADF) from the Menindee Lakes at times when sufficient water is available in the lakes. The intent of the ADF rules is a 'use it or lose it' principle whereby additional water is delivered to South Australia to reduce river salinities, rather than lose the water as evaporation from Menindee Lakes.

Under the ADF rules, South Australia receives 3,000 ML/day above the daily equivalent of the monthly entitlement flow whenever storage levels concurrently exceed both the triggers in the Menindee Lakes and combined Hume/Dartmouth storage (see Table 2 MDBA (2010b)).

Table 8-2: Additional dilution flow storage triggers (GL).

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Menindee Storage	1,300	1,300	1,300	1,300	1,300	1,650	1,650	1,500	1,300	1,300	1,300	1,300
Hume & Dartmouth Storage	2,000	2,000	2,000	2,000	2,000	2,000	2,000	2,000	2,000	2,000	2,000	2,000

8.1.3 Regulation of South Australian River Murray flows

Flows of water in the River Murray to South Australia are regulated by releases of water from Hume Weir, Lake Victoria, and Menindee Lakes, with Dartmouth Dam providing inter-annual regulation.

Much of South Australia's entitlement flow is delivered as a regulated release from Hume Dam, the Menindee Lakes and Lake Victoria, particularly during the summer and autumn months when unregulated flows are generally lower and water demands are high. During the winter and spring months, system inflows are generally higher, with high upstream unregulated flows contributing to, and exceeding, South Australia's entitlement flow.

The annual average and median flows of River Murray water to South Australia are 6,750 gigalitres and 4,600 gigalitres respectively (modelled flows under current conditions for the period 1891 to 2000), which are significantly higher than South Australia's entitlement flow of 1,850 GL/year (SA MDB NRM Board 2009).

8.1.4 South Australian River Murray licences

The framework for water planning and management in South Australia is established under the *Natural Resources Management Act 2004* (SA). Under this Act a water resource may be prescribed, and if prescribed, the relevant regional Natural Resource Management Board will prepare a Water Allocation Plan. This plan guides the distribution of water access entitlements, the determination of water allocations and sets conditions for the taking and use of water. In this instance, the relevant plan is the Water Allocation Plan for the River Murray Prescribed Watercourse (the WAP) (SA MDB NRMB 2009).

In 2009, water rights and responsibilities were unbundled in South Australia. This effectively enabled simpler and faster trade of water allocations and water entitlements. Previously, one licence contained all the specifications for entitlement allocation and use of water. Now, four separate pieces of legal authority allow for use of water in the South Australian River Murray (DWLBC undated). These are:

- Water Access Entitlement—ongoing right to a specified share of the water resource, set out on a water licence. This asset can be sold or transferred permanently or for a limited period.
- Water Allocation—right to take a specific volume of water for a given period of time, not exceeding 12 months. This right will specify the actual volume of water able to be used. The actual volume may vary depending on how much water is available, and is determined and announced by the South Australian Minister for the River Murray at the beginning of a water year (financial year). This asset can be sold.
- Water Resource Works Approval—permission to construct, operate and maintain works (such as a pump, well or dam) to take water at a particular location in a particular way. The requirement to meter the water taken from the resource is connected to this approval. This permission is not transferable to another location.
- Site Use Approval—permission to use water at a particular location in a particular way. This permission is not transferable to another location.

The WAP describes nine classes of Water Access Entitlements. These were established to reflect the reliability and transferability of the water. The classes do not necessarily reflect purpose of use, however they align to individual or groupings of the former purpose-based allocations as outlined in Table 8-3 (SA MDB NRM Board 2009).[3]

Table 8-3: South Australian River Murray water access entitlements.

Class No	Former class type	Maximum no. of unit shares	Maximum allocation (GL)	Water access entitlements endorsed on 2011 licences (unit shares)
Class 1	Stock and domestic	8,704,910[(1)]	8.7	8,375,134
Class 2	Urban use—country towns	50,000,000	50.0	50,000,000
Class 3a	Irrigation	565,057,136	565.1	545,009,002
Class 3b	Irrigation			19,765,134
Class 4	Recreation	4,423,526	4.4	4,428,526
Class 5	Industrial and industrial dairy	5,519,841	5.5	5,519,841
Class 6	Urban use—metropolitan Adelaide	130,000,000	130.0[(2)]	130,000,000
Class 7	Environment	38,366,550	38.4	38,366,550
Class 8	Environmental land management	22,200,000	22.2	21,426,388
Class 9	Wetlands	200,000,000	200.0	33,421,070
Total		**1,024,271,963**	**1,024.3**	**856,311,645**

(1) Includes contingency of 1,000,000 shares for additional stock and domestic entitlements.

(2) Maximum allocation is 650 gigalitres over rolling five-year period, with allocations in excess of 130 gigalitres in some years.

Characteristics that differ between Water Entitlement Classes (SA MDB NRM Board 2009, DWLBC 2011b, DFW 2011) include:

- Except for Class 6 and Class 9 entitlements, the maximum volume of water that can be made available for allocation is 1 kilolitre per unit share. Class 6 are eligible for more than 1 kilolitre per unit share, as the allocation is provided as a five-year rolling entitlement. Thus, some years may receive less or more than 1 kilolitre per share. Class 9 may receive more than 1 kilolitre per share when flows to South Australia are above entitlement.[4]
- South Australian River Murray licences are essentially all high reliability. However, there is no set relative reliability of classes and during periods of drought classes may be prioritised for allocation by the minister.
- A Water Entitlement Class cannot be converted to another class with the exception of conversion between Class 3a and 3b.

3 The former purpose of use class type is no longer applicable since unbundling of water rights that allowed for the separation of use from the access and allocation entitlements.

4 This exception has not been applied to date.

- Classes may differ in eligibility for carryover. Amendments to the Murray-Darling Basin Agreement in 2008 saw the development of Schedule G that accounts for South Australia's storage right. This schedule came into effect on 1 September 2011 and enables carryover of water for critical human water needs and for private carryover of irrigation entitlements. South Australia is currently developing its rules and policy regarding private carryover.
- Water Allocations and Water Access Entitlements may be traded to another person intrastate (except for Class 6 entitlement water allocations). Class 8 and Class 9 allocations can be traded but water use remains subject to conditions of these classes[5] (SA MDB NRM Board 2009)
- Water Access Entitlements cannot be traded interstate. Water allocations on all Classes except Class 6, 8 and 9 cannot be traded interstate[5].
- Class 8 and Class 9 entitlements are restricted on how and where water can be used: allocations obtained on Class 8 can only be used for environmental land management purposes; and Class 9 entitlements can only be used for approved pool-level wetlands. Any conditions for other Classes would be described on the Water Resource Works Approval or Site Use Approval[5].

8.1.5 Determinations/seasonal allocations

Annual water allocations are issued subject to provisions of the *Natural Resources Management Act 2004* (SA) with the minister determining the volume of water available under each entitlement class, taking into account prevailing conditions, for a 12-month period. Generally, allocation announcements are made twice monthly until the maximum is reached.

8.2 Environmental water holdings/provisions

Environmental water can be allocated to made available for water use actions outlined in this plan from allocations against entitlements held by the Commonwealth and The Living Murray (from a total allocation of 485 gigalitres for the designated icon sites); unregulated flows; and water made available from the South Australian Government to allocate to environmental watering actions.

8.2.1 Commonwealth environmental water holdings

Commonwealth Environmental Water manages water acquired through the *Restoring the Balance in the Murray–Darling Basin Program* and water saved through funding infrastructure and other water delivery efficiencies through the *Sustainable Rural Water Use and Infrastructure Program*. The Australian Government holds water access entitlements under relevant state or territory legislation, and is bound by the same rules, restrictions and fees that apply to all holders of water access entitlement in each jurisdiction (SEWPaC 2011).

It is envisaged that the Commonwealth water portfolio will continue to increase over time. As at 4 October 2011, Commonwealth environmental water included 739,536 megalitres in the southern connected basin and 1,062,066 megalitres in the entire Murray-Darling Basin. Of this volume, the Commonwealth held 72,679 megalitres of South Australian Water Access Entitlements. These entitlements are Class 1 (43 megalitres) and Classes 3a and 9 (72,636 megalitres). Updated information on the Commonwealth's environmental water portfolio can be found at: http://www.environment.gov.au/ewater/about/holdings.html

In order to satisfy the environmental water requirements in South Australia it will be necessary to trade water into the state from upstream. Rules governing how water can be traded and delivered to South Australia are specified in the Murray-Darling Basin Agreement.

5 These restrictions do not apply to Class 9 water access entitlements traded to the Commonwealth, and allocations against these entitlements.

8.2.2 South Australian environmental water provisions

Of the South Australian River Murray Water Entitlement Classes, there are two that are relevant to the environment: Class 7 and Class 9 (refer to Table 8-3).

Class 7 licences comprise the South Australian entitlements under The Living Murray entitlements (36,662,218 shares), some private environmental water entitlements (1,699,333 shares), and an entitlement held by the South Australian Minister for the River Murray (4,999 shares) (DFW 2011, pers. comm., 19 May). The minister's entitlement is not necessarily for environmental use, and is not available to be assigned to watering actions.

Class 9 entitlement volume is provided for from the dilution and loss share of South Australia's entitlement flow. The portion of shares associated with this class corresponds to the estimated annual average evaporative loss from all pool-level wetlands (200,000 megalitres) and so Class 9 has been assigned 200,000,000 unit shares.

Of the 200,000,000 Class 9 shares, currently only 33,421,070 are assigned to entitlements, as not all pool-level wetlands are managed and require an allocation. Of these shares, with the exception of a Water Access Entitlement for Banrock Station, are held by the South Australian Minister for the River Murray to enable a coordinated approach to management of the pool-level managed wetlands (DFW 2010, pers. comm.).

A list of current pool-level managed wetlands that are approved for entitlement is provided in Appendix 3. New entitlements may be granted by the South Australian Minister for the River Murray as more pool-level wetlands become regulated. The WAP outlines a number of requirements that must be met for these wetlands to obtain licences, including having a comprehensive management plan. The Environmental Water Management Team of the South Australian Department for Water (DFW) is currently revising the process for managing water allocations for pool-level managed wetlands.

Class 8 Water Access Entitlements may only be used for environmental land management within the Lower Murray Reclaimed Irrigation Area. Allocations are provided for the amelioration of threats such as soil salinisation, subsidence and acidification (SA MDB NRM Board 2009). Generally, Class 8 Entitlements are not used for wetland management or restoration. Paiwalla Wetland (located below Lock 1) has a Class 8 Water Access Entitlement and presents an exception as the wetlands have been restored from an irrigated dairy farm in the Lower Murray Reclaimed Irrigation Area.

The South Australian Government owns limited Water Access Entitlements that can be allocated to environmental watering actions. The use of allocations against Class 9 Water Access Entitlements is limited to managed pool-level wetlands. In the past, water has been purchased on the open market for use on ecological assets and donations have been actively sought (Stribley & Goode 2008).

Water requirements of pool-level managed wetlands (refilling to pool-level and evaporative losses) should be met by the Class 9 shares. During periods of drought these wetlands may not receive water as the wetland may become disconnected from the main channel if river levels drop, or the regulating structures may be closed so that evaporative savings can be made for other water needs in South Australia.

During the recent drought, South Australia made water savings by closing pool-level managed wetlands to assist in meeting water for critical human needs, irrigators and the support of water levels in the Lower Lakes (DEH 2010). During October 2006, all pool-level managed wetlands were disconnected for watering savings. During 2007, six additional un-managed sites were closed (Lake Bonney, Ross Lagoon, Jaeschke Lagoon, Yatco Lagoon, Murbko South wetland and Nelwart Lagoon) following decision by the South Australian senior officials group. Three of these unmanaged sites (Murbko South, Yatco and Nelwart) had permanent management infrastructure installed at this time. While this situation occurred during the drought in the late 2000s, it will not necessarily re-occur should similar conditions arise (DFW 2011, pers. comm.).

8.2.3 Cross-jurisdictional environmental water holdings

The Living Murray program (TLM) is a partnership of all Murray-Darling Basin states and territories. The partner governments committed to recovering 500 gigalitres of water for use at six Living Murray icon sites. Representatives from the partner governments make up The Living Murray Environmental Watering Group which develops an annual (water year) watering plan designed to make best use of available resources. Allocations may not be distributed evenly across sites each year, instead watering will be assigned to associate with natural flooding events. The Environmental Watering Group meets regularly during the year to make recommendations to the MDBA on TLM environmental water use.

8.3 Water availability forecasts

A description of the likely water availability and flows into the lower River Murray is provided fortnightly by the MDBA and DFW. Flood peak estimates within South Australia are provided by DFW based on information supplied through the MDBA River Operations Group, which can provide four to six week projections (assuming no additional system inputs).

Access to this information is available through the following web sites:

- DFW: www.waterforgood.sa.gov.au/news-info/publications/river-murray-flow-advice/
- MDBA: www.mdba.gov.au/water/river_info/weekly_reports

9. Monitoring, evaluation, and improvement

9.1 Existing monitoring programs and frameworks

An extensive range of monitoring programs exist to monitor ecosystem diversity and environmental parameters in the area of the Coorong, Lower Lakes and main channel below Lock 1 in response to watering regimes. These programs are maintained through coordinated efforts between the South Australian Environment Protection Authority (EPA), the South Australian Research and Development Institute (SARDI), SA MDB NRM Board, DENR and the DFW. Funding and project management for monitoring is sourced through DFW (The Living Murray) and DENR (Murray Futures). Monitoring programs are coordinated between both agencies. The monitoring programs are described in Table 9-1 however they are likely to vary with changes to funding availability and monitoring priorities.

These programs would provide sufficient information to monitor the effectiveness of an improved water regime over a long time frame.

Table 9-1: Current monitoring and evaluation in the Coorong, Lower Lakes and main channel below Lock 1

Monitoring parameter	Description	Timing/ frequency of monitoring	Data custodian
Water quality and phytoplankton	Analyses are performed in the field and in the laboratory to assess the condition of the water body against ANZECC guidelines (ANZECC 2000) and predetermined trigger values. **Field analysis**: pH, alkalinity filtered and unfiltered, acidity (if required), temperature, dissolved oxygen, salinity, oxidation reduction potential **Laboratory analysis**: algae, alkalinity as calcium carbonate, acidity as calcium carbonate, aluminium—acid extractable and dissolved, arsenic—total and dissolved, bicarbonate, calcium, chloride, chromium—total and dissolved, cobalt, copper—total and dissolved, conductivity, iron—total and dissolved, magnesium—total and dissolved , manganese—total and dissolved, nickel—total and dissolved, nitrogen—total and nitrate and nitrite and TKN, pH, phosphorus—total and dissolved, potassium—total and dissolved, salinity, selenium—total, sodium—total and dissolved, strontium—dissolved, sulfate, sulfur, and turbidity.	Water quality—fortnightly Phytoplankton—monthly	EPA (SA)
	Between Lock 1 and Wellington the SA MDB NRM Board manages the Community Stream Sampling program that undertakes monitoring of stream tributaries. Monitoring includes water quality testing of ambient water samples as well as macroinvertebrate study and community observations. This monitoring program complements studies undertaken as part of the ongoing monitoring of managed wetlands in the area.	Quarterly—seasonally	SA MDB NRM Board
Benthic macroinvertebrates	At each of the sites, 10 replicate samples are taken haphazardly close to the current water line, and at the locations of the previous water line, which are now submerged. To characterise benthos sediment conditions the samples are taken below, at, and above, current water level. Three samples (to account for small-scale variability) for grain size are taken at each sampling location and pooled into one sample per site. Samples for sediment organic matter are taken at each sampling date again by taking 3 replicate samples that are pooled. Samples for microphytobenthic biomass (Chl-a) are taken. One Chl-a sample is taken per location. All sediment samples are frozen until laboratory analyses are carried out.	Bimonthly, annually	Flinders University
Zooplankton	Three replicate samples are taken in approximately knee-deep water at each site, using a 200 µm mesh plankton net. The sample is scanned by row in a 125 mm^2 gridded Greiner tray. Zooplankton is identified to the lowest taxonomic level as follows: • Rotifera: All known Australian rotifers can be keyed from Shiel (1995) and the more recent guides to the *Identification of the Microinvertebrates of the Continental Waters of the World* series (Backhuys, Netherlands). • Cladocera: Cladocerans may be identified to family and sometimes genus on gross morphology, but to species resolution requires dissection of trunk limbs, post-abdomen or other body parts. • Copepoda: Copepoda can be identified by examination of the dissected limb, antenna or mouthpart structure, depending on group. • Ostracoda: Ostracods require dissection and comparison of furcae, thoracopods and other limb structures. There is no comprehensive key to Australian ostracods, but the papers of De Deckker (2002) provide direction. • Other components: Small macroinvertebrates such as dipteran larvae, hydracarinid mites, barnacle or crab larvae in estuarine conditions, or various other small macroinvertebrates, are identified using appropriate treatment and keys.	Monthly	University of Adelaide

Monitoring parameter	Description	Timing/ frequency of monitoring	Data custodian
Vegetation	The Living Murray Lower Lakes vegetation condition monitoring (Marsland & Nicol 2009) protocol is used. 1x3 m quadrats are established at varying heights on transects running perpendicular to the shore at each site. Cover and abundance of each species present in the quadrat are estimated using the method outlined in Heard and Channon (1997), except that N and T were replaced by 0.1 and 0.5 to enable statistical analyses. The changes in floristic composition through time (seasonal and longer term) are analysed using multivariate analyses, such as clustering, nonmetric multidimensional scaling ordination, PERMANOVA and indicator species analysis.	Spring, autumn each year	SARDI Aquatic Sciences
Fish	Boundary Creek and Mundoo Channel fish assemblages below the barrages.	Bimonthly	University of Adelaide
	This monitoring program samples the 'whole' fish community (i.e. small-bodied and large-bodied and larval life stages) and detects spawning and recruitment. This includes single-wing fyke nets, large mesh gill nets, seine pulls and larval plankton tows. All fish collected from fyke, gill and seine nets are identified to species and counted.	May and Nov each year	SARDI Aquatic Sciences
	Lower Lakes TLM Condition Monitoring of Threatened Fish Species program target Murray hardyhead, Southern pygmy perch and Yarra pygmy perch populations and recruitment using single-wing fyke nets, seine net hauls, box traps and dab nets.	April and Nov each year	University of Adelaide
	Coorong TLM Condition Monitoring for small-mouthed hardyhead, black bream and greenback flounder populations using seine and fyke nets.	Seasonal, depending on species targeted	SARDI Aquatic Sciences

Monitoring parameter	Description	Timing/ frequency of monitoring	Data custodian
Birds	The University of Adelaide—TLM Coorong bird census and habitat monitoring. The Coorong and Murray Mouth is divided into 1 km sections (110 sections): • Murray Mouth estuary (18 sections) • Coorong North Lagoon (44 sections) • Coorong South Lagoon (48 sections). Between 10 to 20 sections are surveyed per day and between 7 and 16 days may be required to complete surveys. Waterbird counts conducted on foot, and by boat. Eastern and western shorelines counted (two observers each). Deeper waterbodies, inaccessible areas and islands counted from a boat (two observers). All waterbirds observed within each 1-km section are recorded. Reported by subsection (e.g. eastern shoreline, western shoreline, centre, island). Behavioural observations recorded (e.g. groupings, distributions), and habitat information relating to chironomid larvae, *Ruppia* spp. and distribution of small mouth hardyhead also collected.	Conducted annually in January	University of Adelaide
	The University of Adelaide also undertakes an annual census of the Lower Lakes, through the TLM program. The lakes are divided into 1 km^2 sections: all birds are counted on foot, using spotting scope and binoculars.	Late January, early February	University of Adelaide
	Australian Wader Studies Group: see Wainwright and Christie (2008), and references therein, for more detail on shorebirds only. North Lagoon, South Lagoon, Murray Mouth Estuary: 25 sections surveyed over two days by land and boat-based teams.	Conducted annually in February	Australasian Wader Studies Group
	Coorong Nature Tours covers fixed sites: • Lake Albert & Alexandrina—23 sites (covering a range of habitats) • Coorong North –10 Sites • Coorong South –10 Sites • Barrage Survey—14 sites. Each site is scanned in an arc radius of approximately 1.5 km. All bird species and numbers viewed are recorded. Special attention is paid to unusual birds for accurate identification (up to 30 mins). All flagged birds observed are recorded and submitted to Birds Australia, a national environmental and research group.	Monthly	SA MDB NRM Board, Coorong Tours Data maintained by DENR in digital database (SVY 177)

Monitoring parameter	Description	Timing/ frequency of monitoring	Data custodian
Frogs	Southern bell frog census of the Lower Lakes: nocturnal surveys are undertaken at sites with suitable habitat using call recognition, call playback and spotlighting techniques. Tadpole surveys undertaken using bait traps and fyke nets.	Nocturnal surveys—October, November and December. Tadpole surveys during January and February	SA MDB NRM Board
Managed wetlands	The SA MDB NRM Board has an ongoing wetland monitoring program at the following Lower Lakes wetlands: Narrung, Teringie, Waltowa, Dunn's Lagoon, Loveday Bay (Jennie's Lagoon) and Milang. Wetlands monitored in the river channel below Lock 1 to Wellington include Sweeney's Lagoon, Morgans Lagoon, Sugarshack wetland, Reedy Creek wetland, Paiwalla, and Rocky Gully wetland. At these wetlands the following parameters are monitored with assistance from community and landholders: water quality and level, groundwater quality and level, photopoints, vegetation, fish, frogs and birds. Monitoring of each parameter does not necessarily occur at each site (depends on site characteristics).	Most parameters quarterly	SA MDB NRM Board
Morella release via Salt Creek (DWLBC 2009): The following monitoring activities will be undertaken for the duration of the release.			
Aquatic habitat and biota monitoring, with quarterly waterbird monitoring.		Quarterly	DFW
Gauging of Morella Basin water levels, temperature and EC (continuous monitoring).		Daily	South Eastern Water Conservation and Drainage Board
Gauging of release volumes, temperature and EC through Morella Regulator (continuous monitoring).		Continuous	South Eastern Water Conservation and Drainage Board
Monitoring of water quality parameters at Morella Basin, Salt Creek and in the mixing zone of the release in the Coorong.		Pre, during and post release	DFW
Nutrient load (Total N and P) monitoring in conjunction with the EPA for the 09/10 release.		Weekly	EPA
Monitoring of Coorong water level, salinity and flow velocity at Snipe Island (A4261165) and Parnka Point (A4260633).		Daily	DFW

9.2 Flow monitoring sites

Hydrological monitoring suitable for environmental water delivery is also incorporated within existing monitoring and operation recording systems. Specifically this includes:

- Continuous flow measurements at Gauging Station 426200 on the River Murray downstream of Rufus River.
- Continuous water level and salinity measurements along the River Murray between Gauging Station 426200 and Wellington, as well as in Lake Alexandrina.
- Regular bathymetry and aerial photography of the Murray Mouth (every six weeks at present).

The only point were environmental water can be accurately accounted for is at the South Australian border.

There is a velocity index rating gauging station at Morgan and also staged index rating stations at Overland Corner and Lyearup. All of the locks can estimate flow however this is more accurate at lower flows, and so flow information through these structures are estimates only. Flow is not measured at the barrages, instead it is estimated based on a rate of 300 ML/day per gate/bay (500 ML/day at Mundoo). However, flows can be significantly less when water levels are elevated in the North Lagoon. Annual barrage flows are determined by assessing the water balance calculation. When flows are less than 50,000 ML/day, the estimates of flow past Lock 1 are considered to be more reliable than the estimates for flows over the barrages. At these flow rates the weir panels at Lock 1 are still in place, whereas at higher flows the weir panels are removed and the lock is 'drowned out'.

9.3 Operational monitoring

Water delivery monitoring is required to record how much water was used, and when and how it was delivered (refer to the DSEWPaC operational monitoring report template at Appendix 7). This information is required to account for environmental water use and to refine the effectiveness and efficiency of future watering events.

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Appendix 1

Modelling achievement of ecological targets and water requirements

Source: Christopher Gippel, Fluvial Systems Pty Ltd.

Modelling achievement of ecological targets and water requirements

Background

The ecological objectives, and associated water level, flow and salinity targets to achieve a healthy CLLMM, have been identified. Four bands of annual flow at the barrages have been identified that relate to specific ecological thresholds (Table 10-5).

Table 10-5: Bands of forecast annual flow at the barrages for July to June water year with suggested management responses to meet ecological objectives.

Forecast flow over barrages for water year (July–June)	Management response	Ecological objectives	Frequency of implementation of response
0 to 60 GL/year	• Boost flows to at least 60 GL/year. • Further boost flow as required to achieve salinity target. • Manipulate water level of lakes to achieve target regime.	• Maintain connectivity between the lakes and the estuary. • Achieve a salinity ≤ 1,500 EC. • Achieve water level variability of lakes to maintain health of riparian vegetation.	• Every year
60 to 650 GL/year	• Boost flows to at least 650 GL/year (includes spring fresh of 150 GL in Oct and 80 GL in Nov). • Further boost flow as required to achieve salinity target.	• Achieve the minimum flow required to avoid unrecoverable degradation of ecological health, including stimulating fish recruitment through flows for fishways, attractant flows, spring fresh and maintaining connectivity between the lakes and the estuary. • Achieve a salinity ≤ 1,000 EC. • Maintain functional connectivity at the mouth in the majority of years.	• Meet in at least 95 per cent of years, with non-complying years non-sequential.
650 to 2,000 GL/year	• Boost flows to at least 1,090 GL/year (includes boosting spring fresh to 180 GL in Oct and Nov). • Achieve 2,000 ML/day.	• Additionally, achieve an enhanced degree of openness of the Murray Mouth. • Enhanced spring fresh to increase certainty of stimulating fish recruitment.	• Meet mouth maintenance target in at least 90 per cent of months. • Meet full spring fresh target in 90 per cent of years.
>2,000 GL/year	• Boost flows as required to achieve salinity target.	• Additionally, achieve a salinity ≤ an annual mean of 700 EC to prevent degradation of marine states in the Coorong and achieve a high degree of certainty that the Ramsar-nominated ecological character will be maintained.	• Maintain as the long-term average (meet in at least 50 per cent of years).
	• Periodically boost flows to at least 6,000 GL/year.	• Additionally, achieve a healthy hypersaline state in the South Lagoon.	• Maintain long-term average frequency of every 3.6 years, and maximum interval of 5 years.
	• Periodically boost flows to at least 10,000 GL/year.		• Maintain long-term average frequency of every 10.4 years, and maximum interval of 17 years.

Note: The objectives of each flow band are additional to those of the lesser flow band/s.

Maintaining the water level of the Lower Lakes within the target envelope of seasonal variability has only a minor implication for water allocation. Under the historical water level management regime, for the benchmark scenario (1995 level of development assuming historical climate), the monthly variability in losses from the Lower Lakes was high, with the average ranging from less than 1 gigalitre in June to around 140 gigalitres in December and January. Over the normal water level range of 0.4 to 0.9 mAHD, the surface area of the Lower Lakes varies by approximately 3 per cent, so the seasonal variation in loss was driven by climate (mainly evaporation) seasonality, not variation in lake surface area. Most of the time the water level in the lakes is controlled by barrage operation rather than River Murray inflows, although lake level will fall if inflows are insufficient to offset losses. Lester et al. (2011a) assumed that the average annual losses were 850 gigalitres. The MDBA provided a 114-year MSM-Bigmod modelled daily flow series of benchmark with TLM (The Living Murray) allocations and barrage operation rules to meet an ecologically desirable target range of lake water levels (Table 0-1). Compared with benchmark (assuming historical lake level management regime), this TLM scenario produced overall lower lake levels (Figure 10-1). While this scenario would produce lower losses than under benchmark conditions, the difference would be small as the lake surface area differences in summer would generally be less than 0.5 per cent.

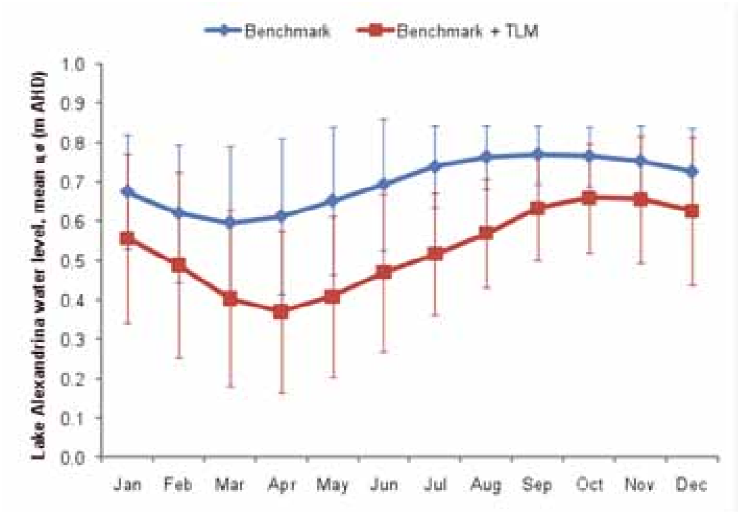


Figure 10-1: Monthly mean (and standard deviation) of water levels for the Lower Lakes for benchmark and benchmark plus TLM with ecologically desirable target lake levels (MSM-Bigmod Run 1009 Benchmark (21967000)).

The steady state annual flow that will sustain less than 1,500 µS cm^{-1} is 1,000 gigalitres, but annual flows less than this (down to 60 gigalitres) are tolerable for individual years, provided the flows in the two previous years are sufficient that salinity remains less than 1,500 µS cm^{-1}. The steady state annual flow that will sustain less than 1,000 µS cm^{-1} is 2,000 gigalitres. When annual flows regularly exceed 2,000 gigalitres, available additional water can be used to reduce salinity towards the target of 700 µS cm^{-1} (annual mean). The long-term average salinity target for the Lower Lakes is 700 µS cm^{-1} (Lester et al. 2011a), which would be approximated by achieving an annual mean salinity of 700 µS cm^{-1} in 50 per cent of years.

By providing sufficient steady baseflow over the barrages each month, the flow in the river would tip the balance in the mouth to a net outward flow that would assist in preventing sediment entering the inlet during a rising tide, and assist in flushing sediment during an ebb tide (Walker 2002). There is an increasing relationship between flow volumes and the relative openness of the mouth (i.e. more flow means that the mouth with be more open). Functional connectivity at the mouth will be maintained in the majority of years by delivering the flows that achieve salinity lower than or equal to 1,000 µS cm^{-1} in the Lower Lakes (Lester et al. 2011a). Close (2002) modelled the impact on risk of mouth closure of maintaining low flows over the barrages of 2,000 ML/day. It was estimated that providing this baseflow would reduce the frequency of risk of mouth closure to about 6 per cent of years, compared to the benchmark scenario with 31.5 per cent of years (Close 2002). Thus, improved connectivity can be achieved with baseflows of 2,000 ML/day. When combined with an enhanced spring fresh, the total annual requirement is 1,090 gigalitres. Target frequencies for these objectives have not been specified in the literature. Logically, the average frequency of year-round low risk of mouth closure occurring jointly with a high certainty of stimulating fish recruitment (through a spring fresh), should fall between that of achieving the 1,000 µS cm^{-1} target (95 per cent of years) and the 700 µS cm^{-1} target (50 per cent of years). Indicative targets for these objectives were set a little lower than their frequency of occurrence in the natural scenario. Compliance with enhanced mouth maintenance flows is best assessed on a monthly basis, rather than annually, which would require achievement of the target flow of 2,000 ML/day in every month of the year to achieve compliance for that year. In the natural scenario, enhanced mouth maintenance flows complied in 96 per cent of months and 74 per cent of years, so the target was set at 90 per cent of months. Compliance with enhanced spring fresh flows was assessed annually. In the natural scenario, enhanced spring fresh flows complied in 96 per cent of years, so the target was set at 90 per cent of years.

Achievement of a healthy hypersaline state in the South Lagoon requires regular flows of 6,000 GL/year and 10,000 GL/year (Lester et al. 2011a). According to Lester et al. (2011a), these flows should continue to be exceeded at the long-term average frequencies characteristic of the benchmark scenario, which they calculated to be every three and seven years respectively. The modelling undertaken for this project utilised a MSM-Bigmod TLM scenario extending from July 1895 to June 2009 and all calculations were based on water year. In this scenario, annual flows exceeding 6,000 gigalitres and 10,000 gigalitres occurred at long-term average frequencies of every 3.6 and 10.4 years respectively, so the long-term targets were set to these frequencies.

The specification of long-term average frequency alone is insufficient information to manage the 6,000 GL/year and 10,000 GL/year flow components, as long-term average is calculated after the event. In order to be able to make decisions in real time about when to augment flows to achieve these thresholds it is necessary to specify for each threshold: (i) a forecast annual discharge that triggers augmentation, (ii) a maximum desirable interval between occurrence of the flow threshold, (iii) a minimum interval (less than the maximum interval) after which the flows can potentially be augmented, (iv) a maximum allocation that can be used to augment the forecast discharge, and (v) a rule that either allows or prevents exceeding the allocation in the event that the maximum desirable interval is exceeded. Lester et al. (2011a) have no advice regarding these requirements, so expert opinion was used to develop the specifications. It was assumed that the maximum tolerable intervals were five years (for 6,000 GL/year target) and 17 years (for 10,000 GL/year target). These correspond to the average frequencies under a median climate change (Lester et al. 2011a). These particular targets were based on expert opinion and should be managed adaptively. Augmentation was allowed after intervals of two years (for 6,000 GL/year target) and eight years (for 10,000 GL/year target). The discharge trigger for using an allocation to augment the flow was set on the basis of the allocation available. These high flow targets would normally be difficult to meet under an allocation cap that would otherwise be adequate to meet the other ecological targets. So, in years when these high flow targets were due to be met, an additional allocation was allowed, under the presumption that these high flow components would be targeted in years of plentiful surplus water. The maximum allocations available to achieve these flows were set to 2,700 gigalitres, with these allocations including any water already held in storage from carryover of the regular allocation. Under these rules the trigger discharges were 3,300 gigalitres (for 6,000 GL/year target) and 7,300 gigalitres (for 10,000 GL/year target). These are large allocations that are likely to be available only in high flow years with large volumes of surplus water. For the scenarios tested here, it was assumed that under normal circumstances these allocations could not be increased in the event that the maximum interval was exceeded (because this usually coincided with a low flow period when large allocations would not be available).

The Framework for Determining Commonwealth Environmental Watering Actions (DEWHA 2009) and the Environmental Working Group (EWG) of the Murray-Darling Basin Authority (MDBA) (MDBA 2009) also utilise a model that outlines management objectives for four different water resource availability scenarios. In contrast to the ecological needs based flow bands identified for the CLLMM (Table 10-5), these are generic flow bands that correspond to prevailing hydrological conditions, specifically:

- extreme dry (lowest annual flow on record)
- dry (30th percentile annual flow)
- median (50th percentile annual flow)
- wet (70th percentile annual flow).

These are arbitrary flow percentiles that do not relate to the appropriate management actions in the CLLMM (for the benchmark MSM-Bigmod flow series, from 1895 to 2009, 60 gigalitres equalled 5th percentile flow, 650 gigalitres equalled 21st percentile flow, and 2,000 gigalitres equalled 43rd percentile flow).

At other Murray-Darling Basin assets, in years of very low flow, when environmental allocations are likely to be highly constrained, high water demand actions such as flooding wetlands can be foregone, and the focus can turn to in-channel ecological processes and pumping relatively small volumes of water to wetlands. In this case the main objective is to avoid irreversible degradation of the assets so that they might recover in a following, wetter, year. At the CLLMM, ecological health is a direct function of total River Murray inflow volume, so as natural flows decrease in dry years, and salinity rises, a higher ecological allocation is required, even to meet bare minimum ecosystem survival requirements. In setting hydrological targets for the CLLMM, this conflict has been taken into consideration. So, for example, in naturally very dry years, the salinity target is higher, and is satisfied by lower flows; in naturally wet years, the target salinity is lower, which takes advantage of the greater likelihood of water availability (Table 10-5). Nevertheless, there is a fundamental reason why, in any particular year, the CLLMM allocation cannot be simply managed on the basis of hydrological conditions forecast to prevail in that year. That is, the salinity balance does not operate on an annual cycle. Fairweather and Higham (2011a) proposed that the minimum flow required in any particular year to meet salinity targets was a function of flow in the previous two years. So, the appropriate management action cannot simply depend on the prevailing hydrological conditions of the current year, but must take into consideration flows over the previous two years. If flows were high in those two years, a completely different response would be appropriate than if the flows were low in those two years.

A Water Delivery Plan would ideally specify the most appropriate way to manage a given allocation in a year having a particular forecast annual flow. If the volume of allocation available for the environment is closely correlated to annual flow in the river, then general management rules can be devised based on predicted annual flow. Water can be allocated to the CLLMM from entitlements held under The Living Murray program, and by the Commonwealth and the South Australian Governments. These might total approximately 1,500 gigalitres per year at most. At this stage there is no information available on which to base predictions about what additional water might become available to the CLLMM under given hydrological conditions. The alternative then is to model the allocation required to meet the ecological targets for a given flow time series, presuming that managers would have been following the water use delivery strategy recommended here (Table 10-5). This approach results in time series' of predicted annual compliance with ecological targets, and allocation used. The flow time series' used in this modelling were derived by MSM-Bigmod.

CLLMM environmental flow model structure

MSM-Bigmod daily time series' modelled for the period July 1895 to June 2009 (inclusive) were obtained from MDBA for the following scenarios:

- natural (assumes no water resources development)
- benchmark run (assumes 1995 level of water resources development)
- benchmark plus TLM contribution (assumes 1995 level of water resources development, and within assumed allocation constraints (i) attempting to meet an ecologically desirable target range of lake water levels (Figure 0-1), and (ii) providing 2,000 ML/day (2,500 ML/day in October to December) over the barrages for maintaining the Murray Mouth in an open state).

Of these three scenarios, the third (benchmark plus TLM) was the most important, as this was used to assess the effectiveness of additional water allocation strategies on achievement of ecological targets. Note that the TLM allocation was used essentially to maintain the Murray Mouth in an open state, and to maintain lake levels within the ecologically desirable range. These are both objectives of the water use delivery strategy recommended by this Water Delivery Plan (Table 10-5).

The natural scenario was used to test whether the ecological targets that form the basis of the water use delivery strategy recommended here (Table 10-5) were met under unregulated flow conditions. It was hypothesised that if these ecological targets were reasonable, they would have a high degree of compliance in the natural scenario. The benchmark series was used to determine the benchmark state of ecological health from which improvements under an augmented flow regime could be compared. In this report, an augmented flow regime is the benchmark regime with new environmental water added, either from The Living Murray (TLM), and/or Commonwealth Environmental Water (CEW).

The natural and benchmark MSM-Bigmod scenarios assume historical climate. This report makes no assumption about the reliability of the historical climate as a guide to the future climate (and therefore future river flows).

The MSM-Bigmod modelled flow series essentially provides 'forecast' flows to the environmental flow model. The model responds to the forecast flows in the most efficient way, because the forecasts are always perfect. The real world situation has inefficiencies, because of incorrect forecasts, and the time lag in responding to unexpected flows. These inefficiencies would result in lower river health compared to the ideal case of perfectly forecast flows.

The environmental flow model estimates the water required to meet CLLMM ecological targets (Table 10-5), calculated at the barrages. The volume of water required to be released from storages (Dartmouth Dam, Hume Dam, Menindee Lakes and Lake Victoria) to meet those needs is higher (due to delivery losses). This report does not attempt to estimate how much water is required to be released from storages to meet ecological targets at the CLLMM. This is a complex optimisation problem that requires consideration of the needs of all of the Basin's ecological assets, other water demands, losses and storages.

In the environmental flow model, the MSM-Bigmod daily flow series is first converted to monthly totals (as flow targets are specified monthly), and dates are redefined as water years (starting 1 July, and ending 30 June). The model then runs through time, comparing the monthly flow with the required monthly total to meet the ecological targets, and the mouth maintenance targets. There is no option to redistribute the forecast annual flow through the months in an effort to meet the ecological targets, because this level of flow control is not available in South Australia. Rather, any monthly shortfalls are met by augmentation, within rules that constrain allocation. Next, the augmented monthly flow series is converted to an annual flow series. To this series the formulas of Lester et al. (2011a) for salinity targets are applied. Any shortfalls are met by augmentation, within rules that constrain allocation. The annual salinity augmentation volumes are then retrospectively distributed by months. This has no effect on the result—it is done only to allow presentation of the augmented time series on a monthly time-step.

The environmental flow model constrains the volume of environmental water available to meet shortfalls. This simply reflects the reality that environmental water allocations are not unlimited. At present, there is no option to carry over environmental water in South Australia. This limitation will not necessarily apply into the future, so the model allowed the option of carry over, up to a specified cap on the volume that could be held in storage. The other parameters were an annual allocation, the unused portion of which could potentially be carried over to the next year. The amount actually carried over was limited by the cap on the volume that could be held in storage, and also by a rule that set the proportion of the unused portion that could be carried over. The latter rule was set to 100 per cent for all model runs reported here. A range of hypothetical values of (i) annual allocation and (ii) cap on allocation held in storage, were run as scenarios. Model output included the volume of allocation actually used, and the volume held in storage, for each year.

As well as reporting flow statistics, the environmental flow model reported compliance with environmental targets. These targets were split into two types, salinity targets, and other needs. "Other needs" lumped fishway flows, attractant flows, flows to maintain connectivity between the lakes and the estuary, spring freshes and mouth maintenance flows. Compliance with 'other needs' was assessed for each month, with the sum of any monthly shortfalls over a water year being the annual shortfall. Compliance with salinity targets of 1,500, 1,000 and 700 µS cm^{-1} were also assessed. According to Lester et al. (2011a), 1,500 µS cm^{-1} is the highest salinity that should occur, 1,000 µS cm^{-1} should not be exceeded in more than 5 per cent of years, and 700 µS cm^{-1} is the ecologically desirable mean salinity (Table 10-5). The targets associated with achievement of 6,000 and 10,000 GL/year were based on the desirable maximum interval between these thresholds (Table 10-5). As the flow augmentation procedure (as defined here) cannot reduce flows, it can be assumed that the target long-term average frequencies of these high flows are met under all management scenarios evaluated here.

The augmented annual flow was regarded as the 'observed' (O) and the annual flow required to meet the ecological targets regarded as the 'expected' (E). In this way, the ratio O/E is a measure of degree of compliance with the target. This is a ratio in the range 0 to 1, with 1 being perfect compliance, and zero only occurring if annual flow is zero. This scale assumes that some ecological benefit is derived from any flow, and that the benefit increases proportionately up to the flow required to meet the target. Flows higher than necessary to meet the target do not score higher than 1. The O/E score was reported on a five-point scale, with 0.2 wide classes. These were: 0 to 0.2 critical, 0.2 to 0.4 very poor, 0.4 to 0.6 poor, 0.6 to 0.8 moderate and 0.8 to 1.0 good. The number of classes, class widths and descriptors are all arbitrary, intended only as a simple device to provide a rapid visual indication of relative health of the CLLMM asset. The other statistic reported for each scenario was the percentage of years in the time series that met the ecological targets.

It is apparent that achieving perfect compliance with the ecological targets would require a large allocation in some years, so the above river health indicators were devised as an aid to the process of balancing river health expectations against water availability constraints.

Ecological compliance of flow scenarios, and allocation used

As expected, the natural flow scenario showed a high level of compliance with the ecological targets, meeting the salinity needs within the desired long-term frequencies (Table 10-6). The other ecological needs were met in 96 per cent of months, but because the non-complying months were scattered throughout the record, only 74 per cent of years had full compliance with other ecological needs (Table 10-6).

The benchmark scenario had low compliance with ecological targets, failing on all required long-term frequencies for salinity targets, and achieving the targets for other needs in only 8 per cent of years (Table 10-6). The Living Murray allocation led to a significant improvement in achievement of other ecological needs, rising to 42 per cent of years targets achieved (Table 10-6). The improvement in achievement of salinity targets was less dramatic. This is explained by the main objective of The Living Murray allocation being to maintain the mouth in an open state.

A scenario was run assuming that there was no constraint on water availability (Table 10-6). For this scenario only, the rules for achieving the 6,000 and 10,000 GL/year targets were adjusted to achieve the desirable long-term average frequency and no better than the maximum frequency (without this adjustment, the frequencies would have been higher than necessary to meet the targets). This scenario revealed the volume of water required in each year to augment the flow with the objective of fully complying with all ecological targets (Figure 10-2 and Figure 10-3). There are some aspects of this scenario that deem it impractical:

- In 22 per cent of years the required allocation exceeds 1,500 gigalitres, and in 9 per cent of years it exceeds 4,000 gigalitres—these volumes can be considered high compared to the volumes that are likely to be available.
- In 19 per cent of years, flow at the barrage has to be more than doubled to achieve the targets.
- In general, higher allocations are required in years of lower flow at the barrages, when in reality, the availability of water for environmental allocations is likely to be lower in such years.

The other scenarios assumed that the allocation was constrained (Table 10-6). These are hypothetical scenarios, intended only to illustrate the trade-off between allocation available and achievement of ecological health targets. Given the unlikelihood of unconstrained allocations being available, it will not be possible to meet all of the ecological targets all of the time, so it is inevitable that some of the time the health of the CLLMM asset will be sub-optimal. Having an effective process for balancing water availability and ecological health will be fundamental to the management of the CLLMM asset.

In the scenarios tested, the hypothetical available allocation of Commonwealth water ranged from 200 to 800 GL/year, and the maximum volume that could be held in storage ranged from 200 to 3,000 gigalitres (Table 10-6). None of the scenarios achieved all of the targets, although an allocation of 800 GL/year with carry over permitted (up to 3,000 gigalitres in storage) failed on only one target (Table 10-6). The requirement of no sequential years with salinity exceeding 1,000 µS cm^{-1} was difficult to meet without a large annual allocation (more than 1,400 GL/year) and large allowable volume in storage (3,300 gigalitres). When the 1,000 µS cm^{-1} salinity target was met in 95 per cent of years, there remained two spells of dry years, in 1943 to 1945 and 2006 to 2008, with sequential non-complying years. The targets for other ecological needs were easier to achieve than the salinity targets. An annual allocation of 500 gigalitres or more, with no carry over, achieved the less than 2,000 GL/year targets in 99 per cent of years. Carryover was of variable importance; it was instrumental in improving compliance with targets for other needs if the annual allocation was low, and it was important in improving compliance with salinity targets if the annual allocation was large (Table 0-6). Success in meeting the 6,000 and 10,000 GL/year targets principally depended on the arbitrary additional volume of allocation provided for this purpose. In reality, the target maximum intervals for these high flows may be difficult to meet, because of the very large allocation that has to be found in some years of only moderate flow.

The water allocation was called on in 67 to 74 per cent of years (Table 10-6). The other years had adequate water to meet all of the targets (Table 10-6).

Illustration of the distribution of Commonwealth water supplied to augment the flow under the constrained allocation scenarios are provided for two scenarios: 300 gigalitres with no carryover (up to 300 gigalitres in storage) (Figure 10-4 and Figure 10-5) and 800 GL/year with carryover permitted (up to 3,000 gigalitres in storage) (Figure 10-6 and Figure 10-7). These scenarios illustrate how allocations are required in years of low to moderate flow, which is the fundamental management problem of the CLLMM asset.

The CLLMM asset health indicator scores were favourable for the entire time series of the natural scenario, except for 2006 to 2008, when the 700 EC salinity target was rated very poor (Figure 10-8). In the benchmark scenario there were periods of high compliance with ecological targets, but overall, the health indicator scores were poor most of the time. The period of worst health was from 2002 to 2008 (Figure 10-8). The TLM contribution led to big improvements in health scores for other needs, such that most years scored good or moderate (Figure 10-8).

Comparing three of the environmental water availability scenarios:

- A scenario with 300 gigalitres' annual allocation and no facility for carryover satisfied the other needs, but the 700 $\mu S\ cm^{-1}$ and 1,000 $\mu S\ cm^{-1}$ targets were only partially met in most years (Figure 10-9).
- A scenario with 800 gigalitres annual allocation and up to 3,000 gigalitres being held in storage almost satisfied all of the targets; the 700 $\mu S\ cm^{-1}$ target was met in approximately half of the years (as desired), and in the non-complying years the health score for this indicator was mostly in the range poor to very poor (O/E score of 0.2 to 0.6) (Figure 10-9).
- A scenario with unlimited allocation available satisfied all of the targets (Figure 10-9). Note that for good ecological health the 700 $\mu S\ cm^{-1}$ target does not have to be met in every year, as the requirement is for this to be the long-term average salinity. This is the main difference in health achieved by this scenario compared to that of the natural scenario (Figure 10-8).

Although having unlimited allocation available achieved all of the ecological targets, the performance of this scenario was only marginally better than the scenario with allocation constrained to 800 gigalitres per year and carryover available, but at an average annual cost of 263 gigalitres per year in additional water.

The monthly distributions of the allocations for the above three scenarios are shown in Figure 10-10, Figure 10-11 and Figure 10-12.

Table 10-6: Compliance of flow scenarios with ecological targets and environmental water use.

Scenario	Salinity targets			Other ecological needs						Other ecological needs combined (for Q < 2,000 GL)		CEW allocation used		
	0 – 60 GL	60 – 650 GL	>650 GL	0 – 60 GL	60 – 650 GL	650 – 2,000 GL		> 2,000 GL						
	1,500 EC % of years met	1,000 EC % of years met	700 EC % of years met	% of years met	% of years met	Mouth open % of mths met	Spring fresh % of years met	6,000 GL max. interval (years)	10,000 GL max. interval (years)	% of mths met	% of years met	% of years called on	Mean (±SD) (GL/year)	Max. (GL/year)
Target	100	95	50	100	95	90	90	5 years	17 years	-	-	-	-	-
Natural	100	98	94	100	100	96	96	3	5	96	74	-	-	-
BM	82	63	31	95	88	51	50	11	22	49	8	-	-	-
BM + TLM	89	71	32	95	92	92	46	11	21	86	42	-	-	-
BM + TLM + CEW 200/200	93	75	38	100	92	93	78	7	14	93	68	74	373 (629)	2,888
BM + TLM + CEW 200/1000	94	76	40	100	95	93	84	7	14	94	76	73	425 (702)	3,664
BM + TLM + CEW 200/2000	94	76	42	100	95	93	85	7	14	94	77	73	428 (702)	3,664
BM + TLM + CEW 300/300	96	77	39	100	96	93	91	7	14	96	83	74	417 (619)	2,888
BM + TLM + CEW 300/1000	96	78	44	100	97	93	94	7	14	97	88	73	502 (745)	3,664
BM + TLM + CEW 300/2000	96	78	45	100	97	93	95	7	14	97	89	73	503 (746)	3,664
BM + TLM + CEW 500/500	97	80	39	100	100	96	100	6	14	100	99	73	505 (659)	3,016
BM + TLM + CEW 500/1000	98	80	46	100	100	96	100	5	14	100	99	71	623 (829)	3,664
BM + TLM + CEW 500/2000	98	81	49	100	100	96	100	5	14	100	99	71	643 (840)	3,664
BM + TLM + CEW 800/800	98	82	43	100	100	96	100	6	14	100	100	72	625 (739)	3,475
BM + TLM + CEW 800/1000	98	85	46	100	100	96	100	5	14	100	100	71	709 (875)	3,664
BM + TLM + CEW 800/2000	98	88	50	100	100	96	100	5	14	100	100	71	775 (951)	3,800
BM + TLM + CEW 800/3000	100	92	51	100	100	96	100	5	14	100	100	71	815 (1,014)	3,930
BM + TLM + CEW unlimited	100	98	65	100	100	96	100	5	17	100	100	67	1,078 (1,713)	8,384

Note: BM = Benchmark, TLM = The Living Murray, CEW = Commonwealth Environmental Water, XXX/YYYY (XXX = annual allocation, YYYY = maximum allocation that can be held in storage. Green shading = target met, red shading = target not met.

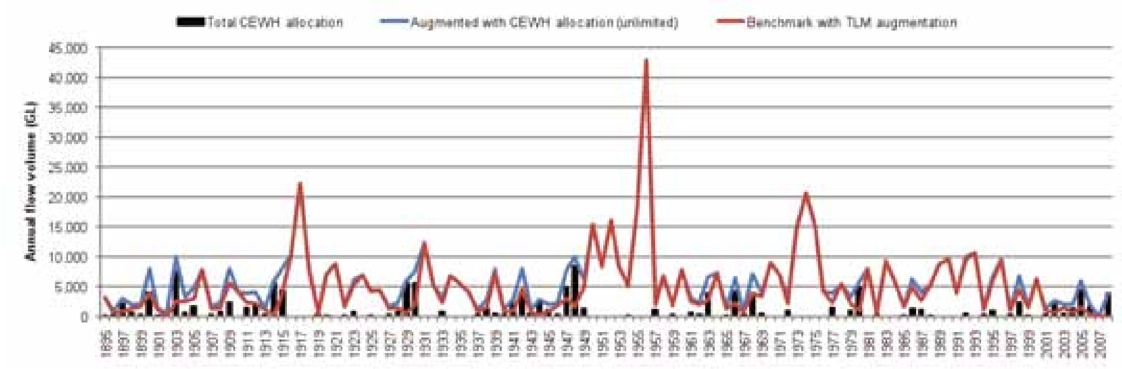


Figure 10-2: Annual flow for the benchmark + TLM scenario and augmented flow scenario, boosted by unlimited Commonwealth allocation to achieve all ecological targets.

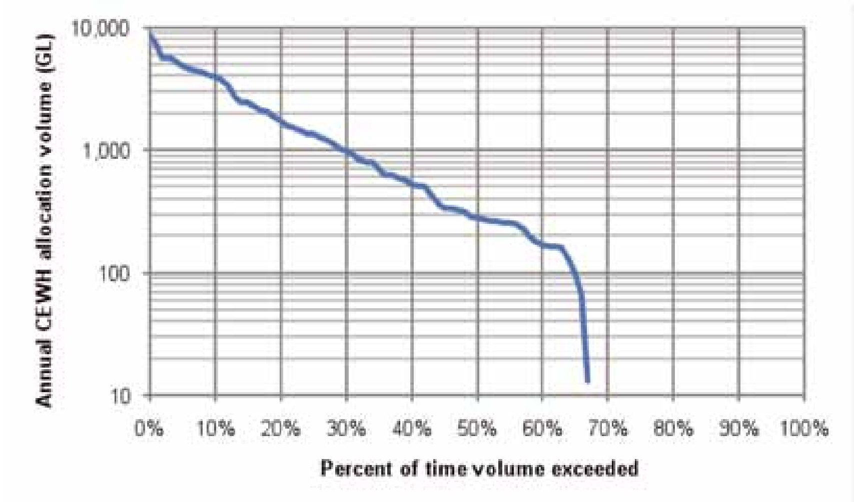


Figure 10-3: Distribution of annual Commonwealth allocation required to achieve all ecological targets, with unlimited allocation availability.

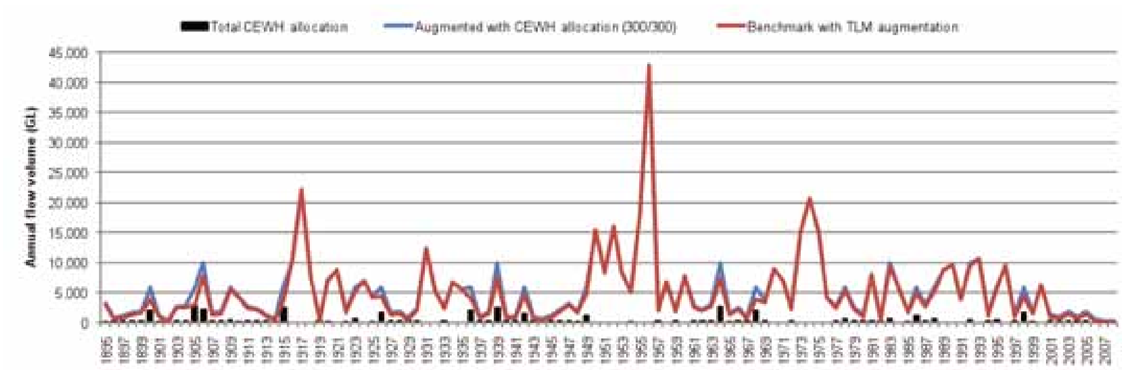


Figure 10-4: Annual flow for the benchmark + TLM scenario and augmented flow scenario, boosted by a constrained Commonwealth allocation of 300 GL/year with no carryover.

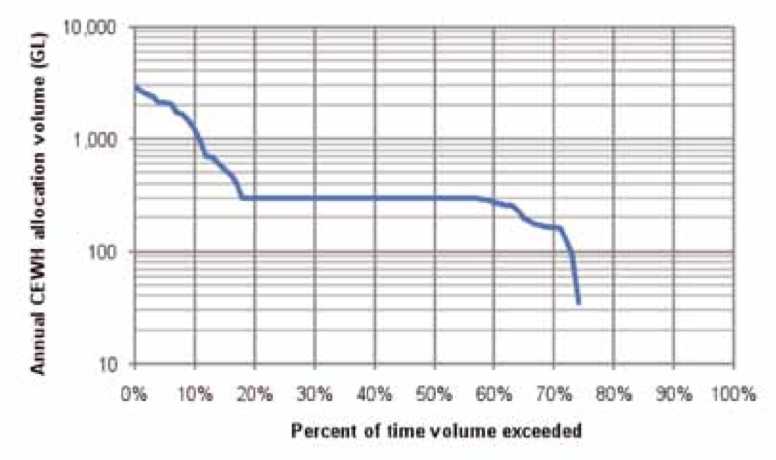


Figure 10-5: Distribution of annual Commonwealth allocation required to achieve all ecological targets, with allocation of 300 GL/year with no carryover.

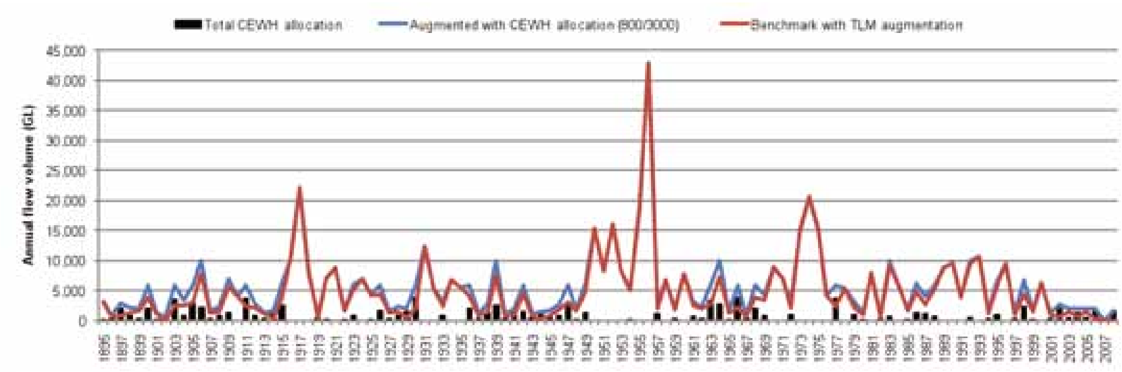


Figure 10-6: Annual flow for the benchmark + TLM scenario and augmented flow scenario, boosted by a constrained Commonwealth allocation of 800 GL/year with carryover that allows up to 3,000 GL to be held in storage.

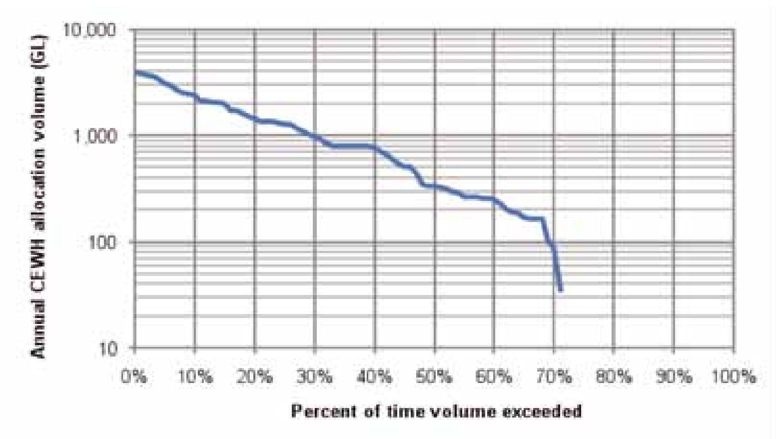


Figure 10-7: Distribution of annual Commonwealth allocation required to achieve all ecological targets, with allocation of 800 GL/year with carryover that allows up to 3,000 GL to be held in storage.

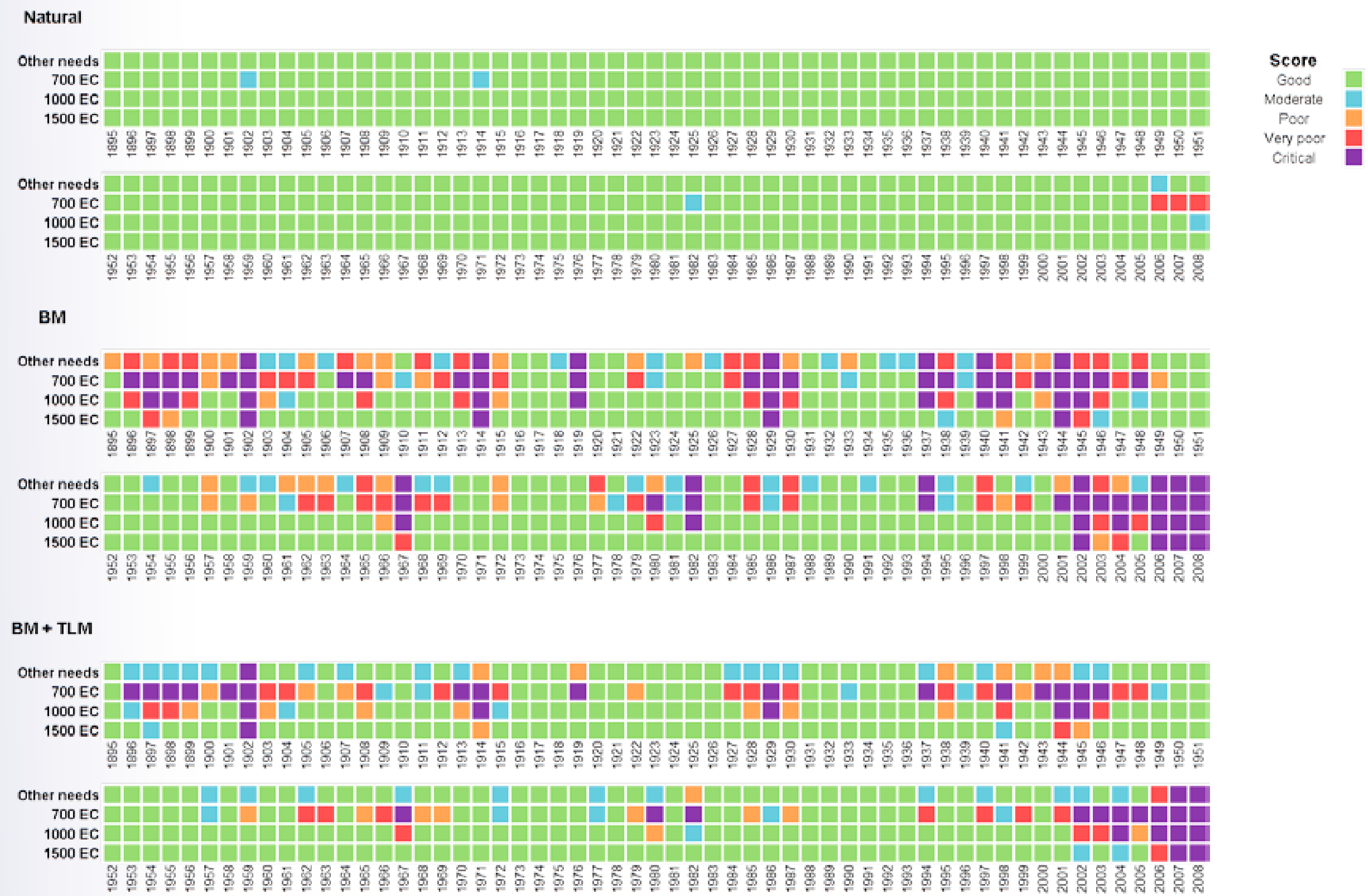


Figure 10-8: Time series of annual CLLMM asset health indicator scores for natural, benchmark and benchmark with TLM augmentation scenarios.

Note: The indicator scores represent O/E ratios, or observed annual flow divided by the annual flow required to fully meet the targets.

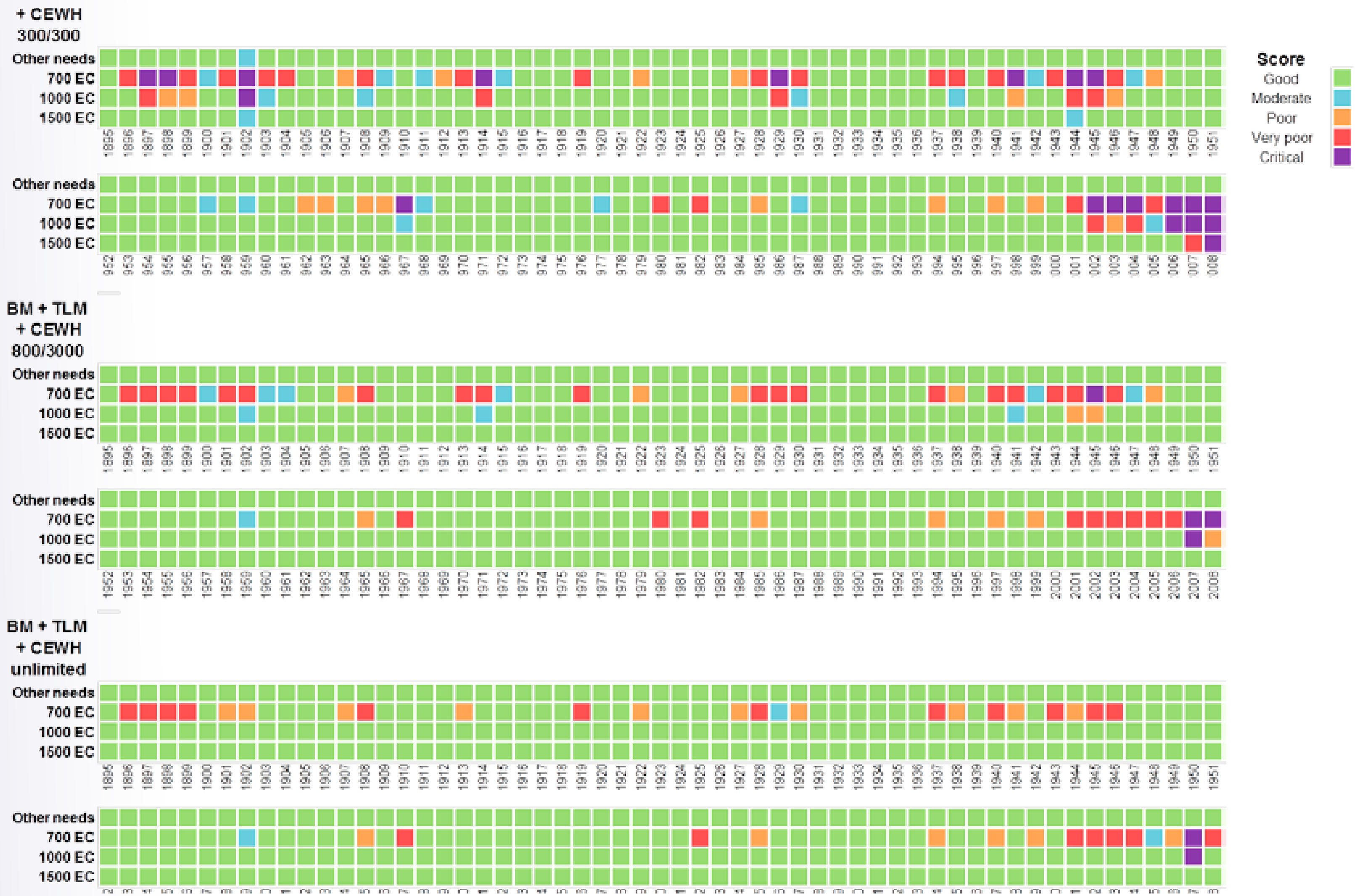


Figure 10-9: Time series of annual CLLMM asset health indicator scores for a range of environmental water availability scenarios.

Note: The indicator scores represent O/E ratios, or observed annual flow divided by the annual flow required to fully meet the targets.

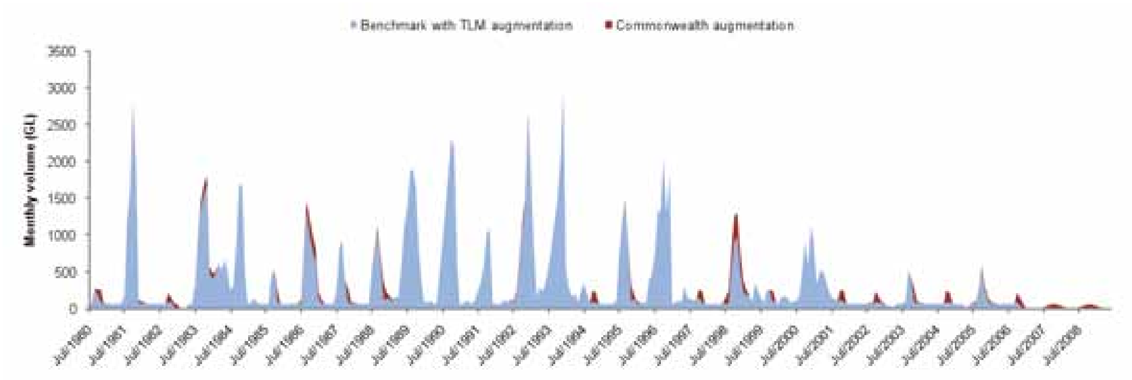


Figure 10-10: Monthly time series of benchmark flows and monthly allocations of Commonwealth water, for a scenario allowing an annual allocation of 300 GL/year and no facility for carryover. The model ran from 1895 to 2008, but only the years from 1980 onwards are shown here.

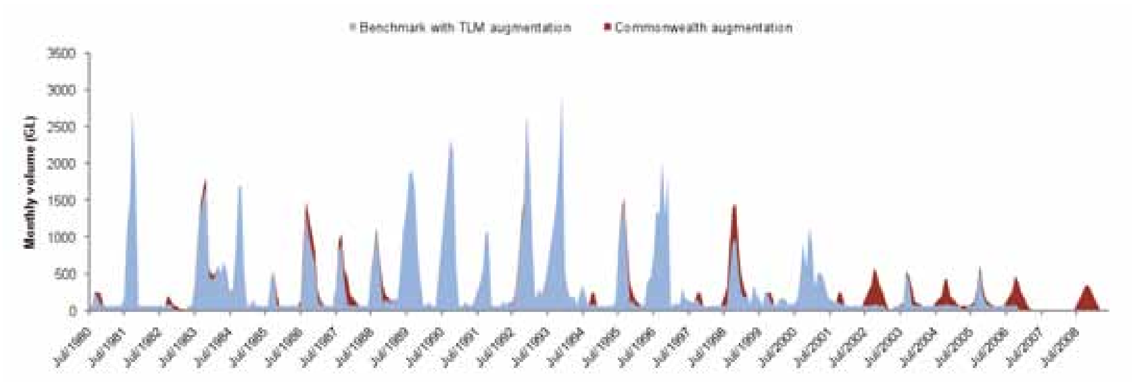


Figure 10-11: Monthly time series of benchmark flows and monthly allocations of Commonwealth water, for a scenario allowing an annual allocation of 800 GL/year and a maximum of 3,000 GL held in storage. The model ran from 1895 to 2008, but only the years from 1980 onwards are shown here.

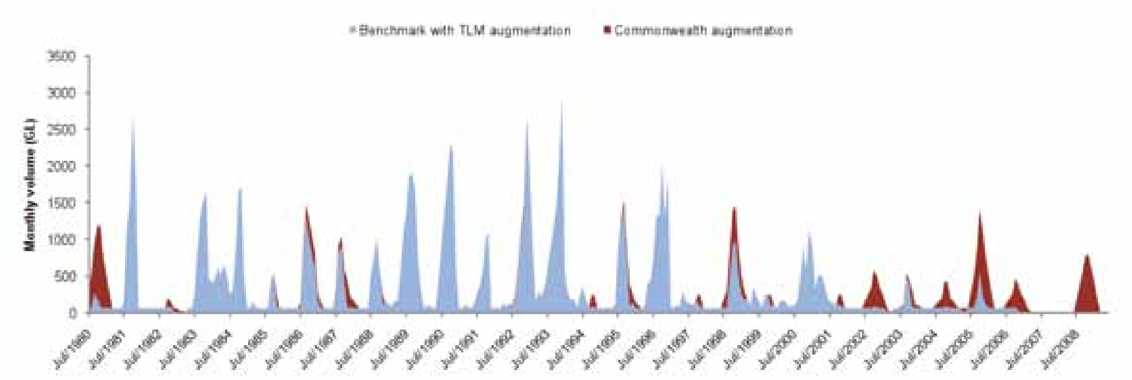


Figure 10-12: Monthly time series of benchmark flows and monthly allocations of Commonwealth water, for a scenario allowing unlimited annual allocation. The model ran from 1895 to 2008, but only the years from 1980 onwards are shown here.

Appendix 2
Case studies of proposed approach for predicting likely water-allocation requirements

Case Study 1: Forecast flow to SA: 2,410 gigalitres, available water allocation is 300 gigalitres.

Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun
62	62	60	78	75	62	62	15	0	0	21	58

1. The forecast flow to South Australia for the year is 2,410 gigalitres. When run through MSM-Bigmod to account for antecedent conditions the forecast flow over the barrages for the year is 555 gigalitres and is distributed as follows:
2. Flow over the barrages in the previous two years were 1,265 gigalitres and 2,094 gigalitres. This creates a target flow over the barrages for the forecast year of 2,735 gigalitres for the 1,000 μS cm^{-1} target and 8,641 gigalitres for the 700 μS cm^{-1} target.
3. The available environmental water is 300 gigalitres.

Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun
68	68	78	79	78	79	79	61	67	66	67	66

4. The total forecast flow over the barrages with additional environmental water is (up to) 855 gigalitres. The highest target that can be achieved is the 650 gigalitre target. The idealised flow distribution is as follows (from Table 5-2):
5. The idealised flow regime incorporates all the requirements for the 650 gigalitre target level plus additional water is provided in October and November in line with the flow requirements for the next highest target regime (the 1,090 gigalitre target regime). It does not however allow for the expected actual distribution of flow hence the allocation release must be apportioned across the year to support the achievement of the target by a combination of natural flow and TLM release water.

   The required additional environmental water (ignoring transfer losses) to best approximate the idealised flow distribution is:

Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun
6	6	18	1	3	17	17	46	67	66	46	8

Which would achieve the following barrage flow regime:

Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun
68	68	78	79	78	79	79	61	67	66	67	66

The 650 gigalitre target regime is achieved in all months.

Alternatively:

a. If an extreme dry period is experienced the highest target that can be fully achieved with additional environmental water is 60 gigalitres. The balance would be put towards the next highest target (with allowance for any minimum lake level top up requirements).

b. If a 30th percentile year is experienced (1,030 gigalitres) a target of 1,095 gigalitres could be achieved in full with 60 gigalitres of environmental water being utilised to firstly achieve the target with the remainder (240 gigalitres) to be used to move towards (but not meet) the higher target of 2,000 gigalitres.

c. If a 50th percentile year is experienced (2,235 gigalitres) a target of 2,000 gigalitres could be achieved in full with the 300 gigalitres of environmental water either being carried over or being utilised to move towards (but not meet) the next higher target of 2,735 gigalitres.

d. If a 70th percentile year is experienced (5,285 gigalitres) a target of 2,735 gigalitres (the 1,000 µS cm^{-1} target figure) could be achieved in full with the 300 gigalitres of environmental water either being carried over or being utilised to move towards (but not meet) the next higher target of 8,641 gigalitres (to achieve the 700 µS cm^{-1} target).

6. The original MSM-Bigmod model run (incorporating provision for TLM water but not other environmental water) through the forecast year identifies that lake levels are expected to fall below the minimum target level from February to June and approximately 232 gigalitres is required over this period to maintain levels above the target minimum. The model must be run with the proposed water allocation to test if the addition of all available environmental water over the spring period is sufficient to avoid missing the lake level target. If it fails to do so the monthly flow allocation would need to be redistributed until this criteria is met.

Case Study 2: Forecast flow to SA: 5,728 gigalitres, available water allocation is 500 gigalitres.

1. The forecast flow to South Australia for the year is 5,728 gigalitres. When run through MSM-Bigmod to account for antecedent conditions the forecast flow over the barrages for the year is 4,121 gigalitres as is distributed as follows:

Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun
193	552	531	789	415	172	66	153	300	551	222	177

2. Flow over the barrages in the previous two years were 5,777 gigalitres and 1,605 gigalitres. This creates a target flow over the barrages for the forecast year of 650 gigalitres for the 1,000 µS cm^{-1} target and 4,618 gigalitres for the 700 µS cm^{-1} target.

3. The available environmental water is 500 gigalitres.

4. The total forecast flow over the barrages with environmental water is up to 4,621 gigalitres. All annual targets can be achieved. The idealised flow distribution is as follows (from Table 5-2):

Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun
402	499	669	745	669	520	445	250	107	104	107	104

The idealised flow regime incorporates all the requirements for the 4,000 gigalitres target level. The flows have been apportioned across the year as per the 4,000 gigalitres flow distribution (by percentages). Comparison between the idealised and the expected actual highlights that the forecast predicts high flows in autumn which exceed the management targets in those months. Conversely the spring flows are lower than desired. All months meet the next lowest target regime (2,000 gigalitres). Hence the environmental water should be used to boost spring flows as all other minimum monthly requirements are met.

The recommended environmental water component (ignoring transfer losses) to best approximate the idealised flow distribution is:

Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun
73	0	48	0	89	122	133	34	0	0	0	0

Which would achieve the following barrage flow regime:

Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun
266	552	579	789	504	294	199	187	300	551	222	177

5. The original MSM-Bigmod model run (incorporating provision for TLM water but no environmental water) through the forecast year identifies that lake levels are not expected to fall below the minimum target level.
6. All targets are met for the ecological responses and the 700 µS cm^{-1} target flow is achieved in this year by the addition of environmental water.

Case Study 3: Forecast for 2011–12: assumed water allocation cap is 300 gigalitres.

1. The adopted forecast flow to South Australia for 2011–12 is as follows and assumes that July and August will be categorised as 'wet' with the balance of the year being median. The forecast flow over the barrages for the year is then 2,980 gigalitres as is distributed as follows:

Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun
491	818	490	524	168	79	62	57	62	60	62	107

2. Flow over the barrages in the previous two years were 9,000 gigalitres (assumed) and zero gigalitres. This creates a target flow over the barrages for the forecast year of 650 gigalitres for the 1,000 µS cm^{-1} target and 3,150 gigalitres for the 700 µS cm^{-1} target.
3. The available environmental water is 300 gigalitres.
4. The total forecast flow over the barrages plus environmental water is (up to) 3,280 gigalitres. All annual targets can be achieved. The idealised flow distribution for 3,150 gigalitres target is as follows (from Table 5-2):

Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun
274	344	461	512	461	362	312	172	97	94	97	94

Comparison between the idealised and the forecast highlights a surplus of flows in winter and a deficit in spring and summer. Hence the available environmental water should be used to boost spring and summer flows as all other minimum monthly requirements are met by the forecast flow. However there is insufficient environmental water to boost both spring and summer flows. Preference is given to boosting spring flows, with the next lower target summer flows still being met.

The recommended environmental water component (ignoring transfer losses) to best approximate the idealised flow distribution is:

Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun
0	0	0	0	84	81	72	33	10	10	10	0

Which would achieve the following barrage flow regime:

Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun
491	818	490	524	252	160	134	90	72	70	72	107

5. Under this forecast scenario it is expected that the original MSM-Bigmod model run (incorporating provision for TLM water but no other environmental water) through the forecast year would identify that lake levels were not expected to fall below the minimum target level.

6. All targets are met for the ecological responses and the 700 µS cm^{-1} target flow is achieved in this year by the addition of 300 gigalitre of environmental water. Total flow over the barrages is 3,280 gigalitres.

Case Study 4: Forecast for 2011–12: assumed water allocation cap is 300 gigalitres.

1. The adopted forecast flow to South Australia for 2011–12 year assumes a 'dry' year compromising a series of 30^{th} percentile for each month. The forecast flow over the barrages for the year is then 1,030 gigalitres as is distributed as follows:

Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun
62	116	199	155	75	62	62	56	62	60	62	60

2. Flow over the barrages in the previous two years were 9,000 gigalitre (assumed) and 0 gigalitres. This creates a target flow over the barrages for the forecast year of 650 gigalitres for the 1,000 µS cm^{-1} target and 3,150 gigalitres for the 700 µS cm^{-1} target.

3. The available environmental water is 300 gigalitres.

Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun
113	113	109	113	109	113	113	102	113	109	113	109

4. The total forecast flow over the barrages plus environmental water is (up to) 1,330 gigalitres. The highest target flow that can be potentially be fully achieved is the 1,095 gigalitre target. The idealised flow distribution for the 1,095 gigalitre target is as follows (from Table 5-2):

   Comparison between the idealised and the forecast highlights a surplus of flow in August and September but a deficit in October and November. The late summer and autumn forecast flows match those for the target distribution. Hence the environmental water should be used to boost the spring (October and November) flows as all other minimum monthly requirements are met by the forecast flow

   The recommended environmental water component (ignoring transfer losses) to best approximate the idealised flow distribution is:

Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun
35	0	0	0	24	35	35	32	35	34	35	34

   Which would achieve the following barrage flow regime:

Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun
97	116	199	155	99	97	97	88	97	94	97	94

5. If the original MSM-Bigmod model run (incorporating provision for TLM water but no other environmental water) through the forecast year identifies that lake levels could fall below the minimum target level then consideration may need to be given to hold back some of the environmental water to ensure the water level targets can be met. This would require a forecast run of MSM-Bigmod with the proposed environmental water releases to test if this were a potential outcome.

6. All targets are met for the flow-based ecological responses and the 1,000 $\mu S\ cm^{-1}$ target flow is also achieved in this year by the addition of environmental water.

7. In this case only 252 gigalitres of the available 300 gigalitre environmental water is required to meet the targets. The balance could be used elsewhere, held in reserve to boost lake levels in autumn, or provide additional flows surplus the target (most likely in spring). The total predicted flow over the barrages for the year is 1,282 gigalitres.

Appendix 3
Pool-level managed wetlands in South Australia that are approved to receive allocations against Class 9 Water Access Entitlements

Lock reach	Wetland
Below Lock 1	Devon Downs South
	Morgans Lagoon LM
	Narrung
	PaiwallaReedy Creek
	Riverglades
	Sugar Shack
	Sweeney's LagoonTeringe
	Waltowa
Lock 1 to 2	Brenda Park
	Morgan Lagoon CP
	Murbpook Lagoon
	Murbko South
Lock 2 to 3	Nigra Creek/Schillers Lagoon (bypasses Lock 2)
	Hart Lagoon
	Ramco Lagoon
Lock 3 to 4	Banrock (bypasses Lock 3)
	Loveday Lagoons (Mussels)
	Loveday North
	Loveday South
	Spectacle Lakes/Beldora
	Yatco
Lock 4 to 5	Causeway Wetland Complex
	Martin Bend
	Nelwart
	Ngak Indau

Lock reach	Wetland
Lock 5 to 6	Lake Merreti
	Lake Woolpoolool
Lock 6 to 7	Pilby Wetland Complex
	Pipeclay Billabong
	Slaney Billabong

Source: H Hill (DFW) 2011, pers. comm., 29 April.

Note: This list is likely to change over time as more wetlands are managed (plans developed and infrastructure installed); and that some of these wetland complexes may contain features that do not receive water at pool level.

For pool-level managed wetlands to obtain a water allocation a Wetland Management Plan must be endorsed by the Department for Water (DFW). These Wetland Management Plans must conform to the "Guidelines for developing wetland management plans for the River Murray in South Australia 2003" (DWLBC 2003).

Appendix 4

Key water dependent species: Lock 1 to Murray Mouth and Coorong

Key:
State Government listing under the National Parks and Wildlife Act 1972 (South Australia)
v = vulnerable
e = endangered
r = rare

International Union for Conservation of Nature Red List of Threatened Species (IUCN)
LC = least concern
NT = near threatened
VU = vulnerable
EN = endangered
CR = critically endangered
DD = data deficient

State Government listing (under the National Parks and Wildlife Act 1972 (South Australia))
v = vulnerable
e = endangered
r = rare

Fauna type	Common name	Scientific name	Species habitat/ presence of species	Breeding status	Coorong	Lower Lakes	Lock 1 to Wellington	EPBC Act	CAMBA	JAMBA	RoKAMBA	IUCN Red list	State gov. listing
Fish	Black bream	*Acanthopagrus butcheri*	MM/estuary	Breed	•								
Fish	Bridled gobi	*Acentrogobius bifrenatus*		Breed		•	•						
Fish	Tamar goby	*Afurcagobius tamarensis*	MM/estuary, N Lagoon	Breed	•								
Fish	Yelloweye mullet	*Aldrichetta forsteri*	MM/estuary, N Lagoon		•								
Fish	Agassiz's glassfish	*Ambassis agassizii*	Historically recorded in Finniss River, not recorded since 2003/present.			•							e

Fauna type	Common name	Scientific name	Species habitat/ presence of species	Breeding status	Coorong	Lower Lakes	Lock 1 to Wellington	EPBC Act	CAMBA	JAMBA	RoKAMBA	IUCN Red list	State gov. listing
Fish	Longsnout flounder	*Ammotretis rostratus*	MM/estuary, N Lagoon		•								
Fish	Short-finned eel	*Anguilla australis*	Historically recorded in Lake Alexandrina (Alex). Not recorded since 2003/ present.			•							r
Fish	Bridled goby	*Arenigobius bifrenatus*	MM/estuary	Breed	•								
Fish	Mulloway	*Argyearosomus hololepidotus*	MM/estuary		•							EN	
Fish	Australian herring	*Arripis georgianus*	MM/estuary, N Lagoon		•								
Fish	Western Australian salmon	*Arripis truttaceus*	MM/estuary, N Lagoon		•								
Fish	Smallmouth hardyhead	*Atherinosoma microstoma*	MM/estuary, N Lagoon, S Lagoon/abundant.	Breed	•								
Fish	Silver perch	*Bidyanus bidyanus*	Historically recorded in Lake Alex. Not recorded since prior to 2003/ present.			•						VU	e
Fish	Murray hardyhead	*Craterocephalus fluviatilis*	Recorded at two sites in Lake Alex in Nov 2008, but were not detected in March 2009 (Wedderburn & Barnes 2009). Recorded Lock 1 to Wellington/present.	Breed		•	•	VU				EN	e
Fish	Australian anchovy	*Engraulis australis*	MM/estuary, N Lagoon	Breed	•								

Fauna type	Common name	Scientific name	Species habitat/ presence of species	Breeding status	Coorong	Lower Lakes	Lock 1 to Wellington	EPBC Act	CAMBA	JAMBA	RoKAMBA	IUCN Red list	State gov. listing
Fish	River black fish	*Gadopsis marmoratus*	Recorded breeding 2011 in Bremer River.	Breed		•	•						e
Fish	Climbing galaxias	*Galaxias brevipinnis*		Breed		•	•						r
Fish	Barred galaxias	*Galaxias fuscus*	MM/estuary	Breed	•	•		EN				CE	
Fish	Common galaxias	*Galaxias maculatus*	MM/estuary	Breed	•								
Fish	Mountain galaxias	*Galaxias olidus*	Recorded in Finniss River in 2003, not recorded since then/present.	Breed		•							v
Fish	Pouched lamprey	*Geotria australis*	Murray estuary Historically recorded in Lake Alex. Not recorded since 2003/present.	Breed	•	•							e
Fish	Soldier	*Gymnapistes marmoratus*	MM/estuary		•								
Fish	Striped perch	*Helotes sexlineatus*	MM/estuary	Breed	•							LC	
Fish	Ogilby's weedfish	*Heteroclinus heptaeolus*	MM/estuary		•								
Fish	Sandy sprat	*Hyperlophus vittatus*	MM/estuary, N Lagoon		•								
Fish	Western carp gudgeon	*Hypseleotris klunzingeri*			•								
Fish	Midgley's carp gudgeon	*Hypseleotris* sp.				•							
Fish	Hybrid carp gudgeon	*Hypseleotris* spp.				•							

Fauna type	Common name	Scientific name	Species habitat/ presence of species	Breeding status	Coorong	Lower Lakes	Lock 1 to Wellington	EPBC Act	CAMBA	JAMBA	RoKAMBA	IUCN Red list	State gov. listing
Fish	Big-bellied seahorse	*Hippocampus abdominalis*	MM/estuary		•							DD	
Fish	Southern garfish	*Hyporhamphus melanochir*	MM/estuary	Breed	•								
Fish	River garfish	*Hyporhamphus regularis*	MM/estuary, N Lagoon	Breed	•								
Fish	Goldspot mullet	*Liza argentea*	MM/estuary	Breed	•								
Fish	Murray cod	*Maccullochella peelii peelii*	Historically recorded in Lake Alex. Not recorded since prior to 2003/ present.			•		VU				CE	v
Fish	Estuary perch	*Macquaria colonorum*	Murray estuary. Historically recorded in Lake Alex. Not recorded since prior to 2003/ present.	Breed	•	•							c
Fish	Murray rainbow fish	*Melanotaenia fluviatilis*		Breed		•	•						
Fish	Purple-spotted gudgeon	*Mogurnda adspersa*	Recorded breeding 2011 in Paiwalla Wetlands.	Breed			•						e
Fish	Short-headed lamprey	*Mordacia mordax*	Murray estuary. Historically recorded in Lake Alex. Not recorded since prior to 2003/ present.	Breed	•	•							e
Fish	Sea mullet	*Mugil cephalus*	MM		•							LC	
Fish	Southern eagle ray	*Myliobatis australis*	MM		•							LC	

Fauna type	Common name	Scientific name	Species habitat/ presence of species	Breeding status	Coorong	Lower Lakes	Lock 1 to Wellington	EPBC Act	CAMBA	JAMBA	RoKAMBA	IUCN Red list	State gov. listing
Fish	Southern pygmy perch	*Nannoperca australis*	Recorded in Lake Alex in 2003, not recorded since then. Have undergone a significant reduction in distribution and abundance since early 2007 (Wedderburn & Barnes 2009)/present.	Breed		•							e
Fish	Yarra pygmy perch	*Nannoperca obscura*	Recorded in Lake Alex in 2003. Have undergone a significant reduction in distribution and abundance since early 2007. Despite extensive sampling they were not detected within Lake Alex in Nov 2008 or Mar 2009 surveys, and the species is now likely extinct from the Murray-Darling basin (Wedderburn & Barnes 2009)/present.	Breed		•		VU				VU	e
Fish	Bony bream	*Nematalosa erebi*	MM/estuary	Breed	•								
Fish	Western striped grunter	*Pelates octolineatus*	MM/estuary		•								
Fish	Flat-headed gudgeon	*Philypnodon grandiceps*	Murray estuary. Recorded recently in Coorong but only under conditions of freshwater inflow.	Breed	•								r
Fish	Dwarf flat-headed gudgeon	*Philypnodon macrostomus*	Murray estuary. Recorded recently in Coorong but only under conditions of freshwater inflow.	Breed	•								r

Fauna type	Common name	Scientific name	Species habitat/ presence of species	Breeding status	Coorong	Lower Lakes	Lock 1 to Wellington	EPBC Act	CAMBA	JAMBA	RoKAMBA	IUCN Red list	State gov. listing
Fish	Tailor	*Pomatomus saltatrix*	MM/estuary		•								
Fish	Congolli	*Pseudaphritis urvillii*	Murray estuary. Diadromous. Has apparently declined over the past few years, to the point that it was not captured in Mar 2009 (Wedderburn & Barnes 2009). Jennings et al. (2008) found a 99% decline in young of that year for congolli, six months after flow cessation over the barrages between 2006–07 and 2007–08. Accumulations of sexually mature female congolli were present from Sept 2008 to winter 2010 upstream of the Goolwa Barrages/ present.	Breed	•	•							r
Fish	Silver trevally	*Pseudocaranx dentex*	MM/estuary		•								
Fish	Bluespot goby	*Pseudogobius olorum*	MM/estuary	Breed	•								
Fish	Australian smelt	*Retropinna semoni*	MM/estuary	Breed	•								
Fish	Greenback flounder	*Rhombosolea tapirina*	MM/estuary, N Lagoon	Breed	•								
Fish	Australian sardine	*Sardinops neopilchardus*	MM/estuary		•								

Fauna type	Common name	Scientific name	Species habitat/ presence of species	Breeding status	Coorong	Lower Lakes	Lock 1 to Wellington	EPBC Act	CAMBA	JAMBA	RoKAMBA	IUCN Red list	State gov. listing
Fish	Blue sprat	*Spratelloides robustus*	MM/estuary		•								
Fish	Spotted pipefish	*Stigmatopora argus*	MM/estuary		•								
Fish	Freshwater catfish	*Tandanus tandanus*	Historically recorded in Lake Alex: not recorded since 2003/present.	Breed		•							e
Fish	Scary's tasmangoby	*Tasmanogobius lasti*	MM/estuary, N Lagoon	Breed	•								
Fish	Smooth toadfish	*Tetractenos glaber*	MM/estuary		•								
Bird	Australian reed-warbler	*Acrocephalus australis (orientalis)*	Present	Breeding migrant	•	•		m	X		X	LC	
Bird	Common sandpiper	*Actitis (Tringa) hypoleucos*	Rarely recorded/ present in Coorong. Not recorded 2003–2009 in either lake. Recorded Lock 1 to Wellington/ present.	NB Migrant	•	•	•	m	X		X	LC	r
Bird	Chestnut teal	*Anas castanea*		Breed	•	•	•					LC	
Bird	Grey teal	*Anas gracilis*		Breed	•	•	•					LC	
Bird	Australasian shoveler	*Anas rhynchotis*	Population variable with recent low/present in Coorong. Marked decline 2003–2009 in both lakes. Uncommon in 2009. Recorded Lock 1 to Wellington/ present.	Breed	•	•	•					LC	r

Fauna type	Common name	Scientific name	Species habitat/ presence of species	Breeding status	Coorong	Lower Lakes	Lock 1 to Wellington	EPBC Act	CAMBA	JAMBA	RoKAMBA	IUCN Red list	State gov. listing
Bird	Pacific black duck	*Anas superciliosa*		Breed	•	•	•					LC	
Bird	Darter	*Anhinga melanogaster (novaehollandiae)*	Rarely recorded in Coorong, variable estuary/present. Marked decline-to-uncommon in Lake Alex, uncommon in Lake Albert. Recorded Lock 1 to Wellington/ present.	Breed	•	•	•					LC	r
Bird	Cattle egret	*Ardea ibis*	Increase then decline in estuary, not recorded in Coorong/present. Uncommon in Lake Alex, rare in Lake Albert. Recorded Lock 1 to Wellington/ present.		•	•	•		X	X		LC	r
Bird	Intermediate egret	*Ardea intermedia*	Coorong: not recorded since 2000/present. Lower Lakes: not recorded 2003–2009. Recorded Lock 1 to Wellington/present.		•	•	•					LC	r
Bird	Eastern great egret	*Ardea modesta*	Coorong: population decline to very low numbers/present. Common but variable in Lake Alex, marked decline-to-rare in Lake Albert 2003–2009/ present.	No	•	•			X	X		LC	
Bird	Flesh-footed shearwater	*Ardenna carneipes*			•					X	X	LC	r
Bird	Ruddy turnstone	*Arenaria interpres*	Coorong: rare/present.	NB Migrant	•			m	X	X	X	LC	r

Fauna type	Common name	Scientific name	Species habitat/ presence of species	Breeding status	Coorong	Lower Lakes	Lock 1 to Wellington	EPBC Act	CAMBA	JAMBA	RoKAMBA	IUCN Red list	State gov. listing
Bird	Hardhead	*Aythya australis*		Breed	•	•	•					LC	
Bird	Musk duck	*Biziura lobata*	Coorong: variable but at times common/present. Lower Lakes: rare 2003–2009. Recorded Lock 1 to Wellington/present.	Breed	•	•	•					LC	r
Bird	Australasian bittern	*Botaurus poiciloptilus*	Coorong: not recorded recently/present. Lower Lakes: rare 2003–2009/ present.	?	•	•						EN	v
Bird	Sharp-tailed sandpiper	*Calidris acuminata*	Coorong: very common but recent marked decline/present.	NB Migrant	•			m	X	X	X	LC	
Bird	Sanderling	*Calidris alba*	Coorong: variable population from common to absent/ present.	NB Migrant	•			m	X	X	X	LC	r
Bird	red knot	*Calidris canutus*	Coorong: not present in most years/present.	NB Migrant	•			m	X	X	X	LC	
Bird	Curlew sandpiper	*Calidris ferruginea*	Coorong: marked decline/present. Decline 2004–2009 in Lake Alex, increase in Lake Albert in same period/present.	NB Migrant	•	•		m	X	X	X	LC	
Bird	Pectoral sandpiper	*Calidris melanotos*	Coorong: rare not recorded since 2000/ present.	NBMigrant	•	•		m		X	X	LC	r

Fauna type	Common name	Scientific name	Species habitat/ presence of species	Breeding status	Coorong	Lower Lakes	Lock 1 to Wellington	EPBC Act	CAMBA	JAMBA	RoKAMBA	IUCN Red list	State gov. listing
Bird	Red-necked stint	*Calidris ruficollis*	Coorong: large population but recent large decline/present. Trend variable but common in Lake Alex, marked increase in Lake Albert 2003–2009/ present.	NBMigrant	•	•		m	X	X	X	LC	
Bird	Long-toed stint	*Calidris subminuta*	Rare in estuary/present. Lower Lakes: not recorded 2003–2009/ present.	NBMigrant	•	•		m	X	X	X	LC	r
Bird	Great knot	*Calidris tenuirostris*	Coorong: generally uncommon/present.	NBMigrant	•			m	X	X	X	VU	r
Bird	Cape Barren goose	*Cereopsis novaehollandiae*	Coorong: population variable/present. Marked decline-to-uncommon in Lake Alex, rare in Lake Albert 2003 to 2009. Recorded Lock 1 to Wellington/present.	NBMigrant	•	•	•	m				LC	r
Bird	Double-banded plover	*Charadrius bicinctus*		NBMigrant	•	•	•	m				LC	
Bird	Greater sand plover	*Charadrius leschenaultii*	Coorong: not recorded recently/present. Recorded Lock 1 to Wellington/present.	NBMigrant	•		•	m	X	X	X	LC	r
Bird	Lesser sand plover	*Charadrius mongolus*	Coorong: rare/present.	NBMigrant	•			m	X	X	X	LC	r
Bird	Red-capped plover	*Charadrius ruficapillus*			•	•	•					LC	

Fauna type	Common name	Scientific name	Species habitat/ presence of species	Breeding status	Coorong	Lower Lakes	Lock 1 to Wellington	EPBC Act	CAMBA	JAMBA	RoKAMBA	IUCN Red list	State gov. listing
Bird	Australian wood duck	*Chenonetta jubata*		Breed	•	•	•					LC	
Bird	Whiskered tern	*Chlidonias hybridus*			•	•	•					LC	
Bird	Banded stilt	*Cladorhynchus leucocephalus*	Coorong: recent large population increases/ present. Marked decline-to-uncommon in Lake Alex, rare in Lake Albert 2003 to 2009. Recorded Lock 1 to Wellington/ present.	Breed	•	•	•					LC	v
Bird	Black swan	*Cygnus atratus*		Breed	•	•	•					LC	
Bird	Little egret	*Egretta garzetta*	Coorong: uncommon/ present. Lower Lakes: rare 2003–2009. Recorded Lock 1 to Wellington/ present.	Breed: Lake Alex	•	•	•					LC	r
Bird	White-faced heron	*Egretta novaehollandiae*		Breed	•	•	•					LC	
Bird	Black-fronted dotterel	*Elseyornis melanops*		Breed	•	•	•					LC	
Bird	Red-kneed dotterel	*Erythrogonys cinctus*		Breed	•	•	•					LC	
Bird	Latham's snipe	*Gallinago hardwickii*	Lower Lakes: not recorded 2003–2009. Recorded Lock 1 to Wellington/present.		•	•	•	m	X	X	X		r

Fauna type	Common name	Scientific name	Species habitat/ presence of species	Breeding status	Coorong	Lower Lakes	Lock 1 to Wellington	EPBC Act	CAMBA	JAMBA	RoKAMBA	IUCN Red list	State gov. listing
Bird	Brolga	*Grus rubicunda*	Recorded Lock 1 to Wellington/present.				•					LC	r
Bird	Sooty oystercatcher	*Haematopus fuliginosus*	Coorong: uncommon, population established in early 1980s/present.	Breed	•							LC	
Bird	Pied oystercatcher	*Haematopus longirostris*	Coorong: stable/present.	Breed	•							LC	r
Bird	White-bellied sea-eagle	*Haliaeetus leucogaster*		Breed	•	•			X			LC	e
Bird	Black-winged stilt	*Himantopus himantopus*		Breed	•	•	•	m				LC	
Bird	Caspian tern	*Hydroprogne (Sterna) caspia*	Marked decline in estuary, and habitat in Coorong is variable. Marked decline 2003–2009 in both lakes. Rare 2009/present.	Breed	•	•			X			LC	
Bird	Pacific gull	*Larus pacificus*			•	•	•					LC	
Bird	Lewin's rail	*Lewinia pectoralis*	Coorong: rare/present. Lower Lakes: rarely recorded in Lake Alex, not recorded in Lake Albert 2003–2009. Recorded Lock 1 to Wellington/present.	Breed	•	•						LC	v

Fauna type	Common name	Scientific name	Species habitat/ presence of species	Breeding status	Coorong	Lower Lakes	Lock 1 to Wellington	EPBC Act	CAMBA	JAMBA	RoKAMBA	IUCN Red list	State gov. listing
Bird	Bar-tailed godwit	*Limosa lapponica*	Coorong: recent population increases/ present. Lower Lakes: rarely recorded 2003 to 2009/present.	NB Migrant	•	•		m	X	X	X	LC	r
Bird	Black-tailed godwit	*Limosa limosa*	Coorong: population variable/present. Rarely recorded in Lower Lakes 2003–2009. Recorded Lock 1 to Wellington/ present.	NB Migrant	•	•	•	m	X	X	X	NT	r
Bird	Pink-eared duck	*Malacorhynchus membranaceus*			•	•	•					LC	
Bird	Little pied cormorant	*Microcarbo (Phalacrocorax) melanoleucos*		Breed	•	•	•					LC	
Bird	Orange-bellied parrot	*Neophema chrysogaster*	Coorong: recent marked decline to very low numbers/present. Rarely recorded 2003–2009. Recent marked decline evident (Ehmke et al. 2009)/present.	NB Migrant	•	•		CR		X		CE	e
Bird	Eastern curlew	*Numenius madagascariensis*	Coorong: population variable/present. Lower Lakes: not recorded 2003–2009/present.	NB Migrant	•	•		m	X	X	X	VU	v
Bird	Whimbrel	*Numenius phaeopus*	Coorong: historically common but now rare/ present. Not recorded 2003–2009/present.	NB Migrant	•	•		m	X	X	X	LC	r

Fauna type	Common name	Scientific name	Species habitat/ presence of species	Breeding status	Coorong	Lower Lakes	Lock 1 to Wellington	EPBC Act	CAMBA	JAMBA	RoKAMBA	IUCN Red list	State gov. listing
Bird	Nankeen night heron	*Nycticorax caledonicus*		Breed	•	•	•					LC	
Bird	Blue-billed duck	*Oxyura australis*	Coorong: rarely recorded/present. Lower Lakes: rare 2003–2009. Recorded Lock 1 to Wellington/present.	NB Migrant	•	•	•					NT	r
Bird	Eastern osprey	*Pandion cristatus*	Lower Lakes: present. Recorded Lock 1 to Wellington/present.			•		m				LC	e
Bird	Australian pelican	*Pelicanus conspicillatus*		Breed	•	•	•						
Bird	Great cormorant	*Phalacrocorax carbo*		Breed	•	•	•					LC	
Bird	Black-faced cormorant	*Phalacrocorax fuscescens*			•							LC	
Bird	Little black cormorant	*Phalacrocorax sulcirostris*		Breed	•	•	•					LC	
Bird	Pied cormorant	*Phalacrocorax varius*		Breed	•	•	•					LC	
Bird	Red-necked phalarope	*Phalaropus lobatus*	Vagrant/present	NB Migrant	•				X	X	X	LC	
Bird	Ruff	*Philomachus pugnax*	Coorong: rare/present. Lower Lakes: not recorded 2003–2009/ present.	NB Migrant	•	•		m	X	X	X	LC	r

Fauna type	Common name	Scientific name	Species habitat/ presence of species	Breeding status	Coorong	Lower Lakes	Lock 1 to Wellington	EPBC Act	CAMBA	JAMBA	RoKAMBA	IUCN Red list	State gov. listing
Bird	Yellow-billed spoonbill	*Platelea flavipes*		Breed	•	•	•					LC	
Bird	Royal spoonbill	*Platelea regia*		Breed	•	•	•					LC	
Bird	Glossy ibis	*Plegadis falcinellus*	Coorong: not recorded since 2002/present. Lower Lakes: not recorded since 2007, 268 recorded in Lake Alex in 2005. Recorded Lock 1 to Wellington/present.	Breed: Lake Alex	•	•	•	m	X			LC	r
Bird	Pacific golden plover	*Pluvialis fulva*	Coorong: variable in moderate numbers/ present. Lower Lakes: not recorded since 2007, 14 recorded Lake Alex in 2004/present.	NB Migrant	•	•		m			X	LC	r
Bird	Grey plover	*Pluvialis squatarola*	Coorong: uncommon/ present. Lower Lakes: rarely recorded in Lake Alex, not recorded in Lake Albert 2003–2009/ present.	NB Migrant	•	•		m	X	X	X	LC	
Bird	Great crested grebe	*Podiceps cristatus*	Variable in Coorong; marked decline in estuary/present. Lower Lakes: severe decline 2005–2009 to rare in 2009. Recorded Lock 1 to Wellington/present.	Breed	•	•	•					LC	r
Bird	Regent parrot	*Polytelis anthopeplus*	Recorded Lock 1 to Wellington/present.	Breed		•		VU				LC	v

Fauna type	Common name	Scientific name	Species habitat/ presence of species	Breeding status	Coorong	Lower Lakes	Lock 1 to Wellington	EPBC Act	CAMBA	JAMBA	RoKAMBA	IUCN Red list	State gov. listing
Bird	Hoary-headed grebe	*Popiocephalus poliocephalus*		Breed	•	•	•					LC	
Bird	Purple swamphen	*Porphyeario porphyeario*		Breed	•	•	•					LC	
Bird	Australian spotted crake	*Porzana fluminea*		Breed	•	•	•					LC	
Bird	Spotless crake	*Porzana tabuensis*	Lower Lakes: rare 2003–2009. Recorded Lock 1 to Wellington/present.	Breed	•	•	•					LC	r
Bird	Red-necked avocet	*Recurvirostra novaehollandiae*		Breed	•	•	•					LC	
Bird	Australian painted snipe	*Rostratula australis*	Recorded Lock 1 to Wellington/present.	Breed			•	VU	X			EN	v
Bird	Common tern	*Sterna hirundo*	Coorong: rarely recorded/present. Rarely recorded in Lake Alex, not recorded in Lake Albert 2003–2009/ present.	NB Migrant	•	•		m	X	X	X	LC	r
Bird	Gull-billed tern	*Sterna nilotica*			•	•	•	m				LC	
Bird	Little tern	*Sternula (Sterna) albifrons*	Coorong: not recorded since 2000/present. Lower Lakes: not recorded 2003–2009/ present.	Breed: Coorong Islands	•	•		m	X	X	X	LC	e
Bird	Fairy tern	*Sternula (Sterna) nereis*	Coorong: population decline/present. Rarely recorded in Lake Albert, not recorded in Lake Alex 2003–2009/present.	Breed	•	•						VU	e

Fauna type	Common name	Scientific name	Species habitat/ presence of species	Breeding status	Coorong	Lower Lakes	Lock 1 to Wellington	EPBC Act	CAMBA	JAMBA	RoKAMBA	IUCN Red list	State gov. listing
Bird	Freckled duck	*Stictonetta naevosa*	Coorong: uncommon and irregular/present. Lower Lakes: marked decline 2003–2009 in both lakes. Not recorded 2007–2009. Recorded Lock 1 to Wellington/ present.	NB Migrant	•	•	•					LC	v
Bird	Crested tern	*Thalasseus (Sterna) bergii*		Breed	•	•	•	m				LC	
Bird	Hooded plover	*Thinornis rubricollis*	Coorong: uncommon but stable population/ present. Rarely recorded in Lake Alex, not recorded Lake Albert 2003–2009/present.	Breed	•	•						NT	v
Bird	Australian white ibis	*Threskiornis molucca*		Breed	•	•	•					LC	
Bird	Straw-necked ibis	*Threskiornis spinicollis*		Breed	•	•	•					LC	
Bird	Black-tailed native-hen	*Tribonyx (Gallinula) ventralis*		Breed	•	•	•					LC	
Bird	Grey-tailed tattler	*Tringa brevipes*	Vagrant/present	NB Migrant	•			m	X	X	X	LC	r
Bird	Wood sandpiper	*Tringa glareola*	Uncommon in Lake Alex then recent decline to zero, not recorded in Lake Albert 2003–2009/ present.	NB Migrant		•						LC	
Bird	Wandering tattler	*Tringa incana*		NB Migrant	•			m	X	X	X	LC	

Fauna type	Common name	Scientific name	Species habitat/ presence of species	Breeding status	Coorong	Lower Lakes	Lock 1 to Wellington	EPBC Act	CAMBA	JAMBA	RoKAMBA	IUCN Red list	State gov. listing
Bird	Common greenshank	*Tringa nebularia*	Stable in Coorong, increase in estuary/ present. Lower Lakes: decline 2004–2009 in Lake Alex, uncommon Lake Albert in same period/present.	NB Migrant	•	•		m	X	X	X	LC	
Bird	Marsh sandpiper	*Tringa stagnatilis*	Coorong: variable but at times common/present. Lower Lakes: uncommon, but variable in numbers recorded in Lakes Alex and Albert.	NB Migrant	•	•		m	X	X	X	LC	
Bird	Masked lapwing	*Vanellus miles*		Breed	•	•						LC	
Bird	Terek sandpiper	*Xenus cinereus*	Coorong: rare/present.	NB Migrant	•			m	X	X	X	LC	r
Amphibian	Brown toadlet	*Pseudophryne bibronii*		Breed	•	•						NT	v
Amphibian	Golden bell frog	*Litoria raniformis*		Breed	•	•		VU				EN	v
Amphibian	Marbled toadlet	*Pseudophryne semimarmorata*		Breed	•	•						LC	v
Reptile	Long-necked tortoise	*Chelodina longicollis*		Breed		•	•					LC	
Reptile	Macquarie tortoise	*Emydura macquarii*	Recorded Lower Lakes and Lock 1 to Wellington/ present.	Breed		•	•					LC	v
Mammal	Southern myotis	*Myotis macropus*	Recorded Lock 1 to Wellington/present.	Breed			•					LC	e
Flora	Leafy twig-rush	*Cladium procerum*			•	•							r

Note: NB Migrant = winter non-breeder migrant.

Appendix 5
Lake Alexandrina and Lake Albert volumetric data

Lake Alexandrina (including Goolwa Channel)

Water level m (AHD)	Surface area (ha)	Estimated volume[1] (GL)	Increment volume (GL)
0.8	64,912.00	1,651.16	32.44
0.75	64,845.60	1,618.72	32.40
0.7	64,778.67	1,586.32	64.71
0.6	64,652.97	1,521.62	64.57
0.5	64,496.32	1,457.05	64.39
0.4	64,293.79	1,392.66	64.11
0.3	63,906.69	1,328.55	63.54
0.2	63,110.55	1,265.01	62.65
0.1	62,213.89	1,202.36	61.76
0	61,281.82	1,140.60	60.74
-0.1	60,171.80	1,079.86	59.56
-0.2	58,938.03	1,020.31	58.29
-0.3	57,622.92	962.02	56.95
-0.4	56,243.17	905.06	55.40
-0.5	54,304.02	849.67	53.82
-0.6	53,411.39	795.84	52.98
-0.7	52,533.18	742.86	52.05
-0.8	51,609.86	690.81	51.18
-0.9	50,752.39	639.63	50.28
-1	49,804.71	589.35	49.23
-1.1	48,607.59	540.12	47.95
-1.2	47,307.43	492.17	46.66

Water level m (AHD)	Surface area (ha)	Estimated volume[1] (GL)	Increment volume (GL)
-1.3	45,973.43	445.51	45.11
-1.4	44,151.87	400.41	43.13
-1.5	42,180.94	357.27	41.20
-1.6	40,205.64	316.08	39.35
-1.7	38,486.18	276.73	37.72
-1.8	36,872.28	239.01	35.78
-2	32,549.79	169.58	31.17
-2.2	26,081.50	110.51	24.16
-2.4	19,296.92	65.44	17.89
-2.6	12,907.22	32.74	11.52
-2.8	7,136.35	12.75	5.95
-3	2,892.82	3.08	2.55
-3.5	84.06	0.53	0.26
-4	26.19	0.27	0.08
-4.5	11.26	0.19	0.05
-5	8.25	0.14	

1. These volumes are calculated using bathymetry based on Lidar and Sonar spatial data. The vertical accuracy of the LiDAR raw data is +/- 0.15 m. The vertical accuracy of the Sonar raw data collected by the echo sounder is +/-0.1 m. Bathymetry was based on resampled 10 m resolution from source 2 m data. Sonar data points in less than 1 m of water are synthetic due to access restrictions for boat-based sonar and have a stated accuracy of +/- 0.5 mAHD. Sonar was obtained at a time when the lake levels where at 0.75 mAHD, giving a accuracy level of +/- 0.1 m to level of –0.25 mAHD. The LiDAR was flown at a time when water levels were less than –0.4 mAHD, hence the LiDAR more than covers the extent of less accurate Sonar data. As such, the combined bathymetry accuracy can be taken as +/- 0.15 m. Extract by mask using management unit boundary Surface Volume_3D Analyst tool in ArcGIS 9.1. Data source: CLLMM Project, Department of Environment and Natural Resources (2009).

Lake Albert

Water level m (AHD)	Surface area (ha)	Estimated volume[1] (GL)	Increment volume (GL)
0.8	17,187.41	287.56	8.59
0.75	17,175.69	278.97	8.58
0.7	17,163.06	270.39	17.15
0.6	17,133.89	253.24	17.11
0.5	17,096.98	236.13	17.07
0.4	17,042.35	219.07	17.00
0.3	16,960.01	202.07	16.89
0.2	16,821.03	185.18	16.70
0.1	16,590.34	168.47	16.45
0	16,288.82	152.03	16.09
-0.1	15,856.09	135.94	15.60
-0.2	15,369.69	120.34	7.63
-0.25	15,143.34	112.71	7.52
-0.3	14,929.42	105.19	14.70
-0.4	14,473.59	90.49	14.16
-0.5	13,578.86	76.33	12.71
-0.6	12,105.29	63.61	11.75
-0.7	11,341.48	51.87	5.57
-0.75	10,960.28	46.30	5.38
-0.8	10,586.22	40.91	10.13
-0.9	9,673.84	30.78	9.17
-1	8,528.09	21.61	7.58
-1.1	6,653.46	14.03	5.93
-1.2	5,289.60	8.10	4.56
-1.3	3,759.13	3.55	2.68
-1.4	1,525.73	0.87	0.56
-1.5	164.99	0.31	0.12

Water level m (AHD)	Surface area (ha)	Estimated volume[1] (GL)	Increment volume (GL)
-1.6	77.95	0.19	0.03
-1.7	27.67	0.16	0.03
-1.8	25.07	0.13	0.02
-1.9	22.57	0.11	0.02
-2	20.26	0.09	0.02
-2.2	14.79	0.05	0.01
-2.5	7.24	0.02	0.01
-3	1.38	0.00	0.00
-3.4	0.00	0.00	0.00

1. These volumes are calculated using bathymetry based on Lidar and Sonar spatial data. The vertical accuracy of the LiDAR raw data is +/- 0.15 m. The vertical accuracy of the Sonar raw data collected by the echo sounder is +/-0.1 m. Bathymetry was based on resampled 10 m resolution from source 2 m data. Sonar data points in less than 1 m of water are synthetic due to access restrictions for boat based sonar and have a stated accuracy of +/- 0.5 mAHD. Sonar was obtained at a time when the lake levels where at 0.75 mAHD, giving a accuracy level of +/- 0.1 m to level of –0.25 mAHD. The LiDAR was flown at a time when water levels were less than –0.4 mAHD, hence the LiDAR more than covers the extent of less accurate Sonar data. As such, the combined bathymetry accuracy can be taken as +/- 0.15 m. Extract by mask using management unit boundary Surface Volume_3D Analyst tool in ArcGIS 9.1. Data source: CLLMM Project, Department of Environment and Natural Resources (2009).

Appendix 6
Risk assessment framework

Risk likelihood rating

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

Risk consequence rating

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

Risk analysis matrix

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

Appendix 7
Operational monitoring report template

Commonwealth Environmental Watering Program

Operational Monitoring Report

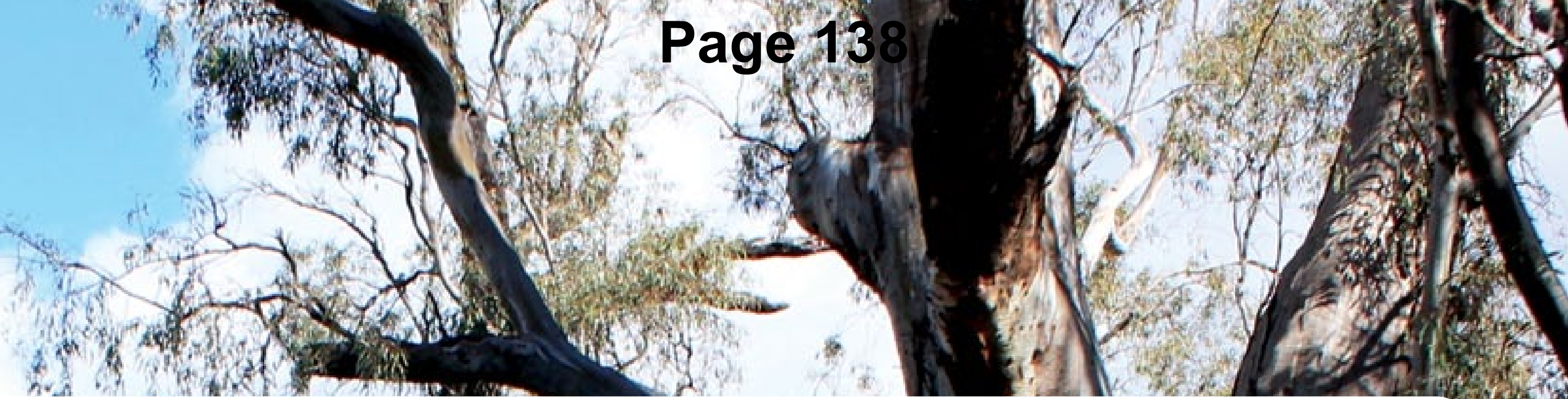
Please provide the completed form to <insert name and email address>, within two weeks of completion of water delivery or, if water delivery lasts longer than 2 months, also supply intermediate reports at monthly intervals.

Final Operational Report Intermediate Operational Report Reporting Period: From To

Site name	**<EWDS to prefill>**	**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) <EWDS to prefill>*	
	Total volume of water allocated for the watering event *CEW:* *Other(please specify) :*	
	Total volume of water delivered in watering event *CEW:* *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.



Australian Government

Commonwealth Environmental Water

ENVIRONMENTAL WATER DELIVERY:

Yarrawonga to Tocumwal and Barmah-Millewa

AUGUST 2011 V1.0

Image Credits

Barmah Forest along the Choke
©DSEWPaC; Photographer Rebecca Gee

Barmah Island and Broken Creek
©DSEWPaC; Photographer Rebecca Gee

The Murray at Fisherman's Bend
©MDBA; Photographer Arthur Mostead

Ecological Associates and SKM (2011). Environmental Water Delivery: Yarrawonga to Tocumwal and Barmah-Millewa. Prepared for Commonwealth Environmental Water, Department of Sustainability, Environment, Water, Population and Communities.

ISBN: 978-1-921733-22-2

SEWPaC acknowledges the following individuals and organizations that have been consulted in the preparation of this document:

Murray Darling Basin Authority
ViC Department of Sustainability and Environment
NSW Office of Environment and Heritage
Goulburn Broken Catchment Management Authority
NSW Office of Water
Murray Catchment Management Authority
NSW State Water
Garry Smith (DG Consulting)
Ben Gawne (Murray-Darling Freshwater Research Centre)
Daren Barma (Barma Water Resources)

Published by the Commonwealth Environmental Water Holder for the Australian Government.

ENVIRONMENTAL WATER DELIVERY:
Yarrawonga to Tocumwal and Barmah-Millewa

AUGUST 2011 V1.0

Environmental Water Delivery: Yarrawonga to Tocumwal and Barmah-Millewa

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.

Commonwealth Environmental Water
Department of Sustainability, Environment, Water, Population and Communities
GPO Box 787, Canberra ACT 2601
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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.

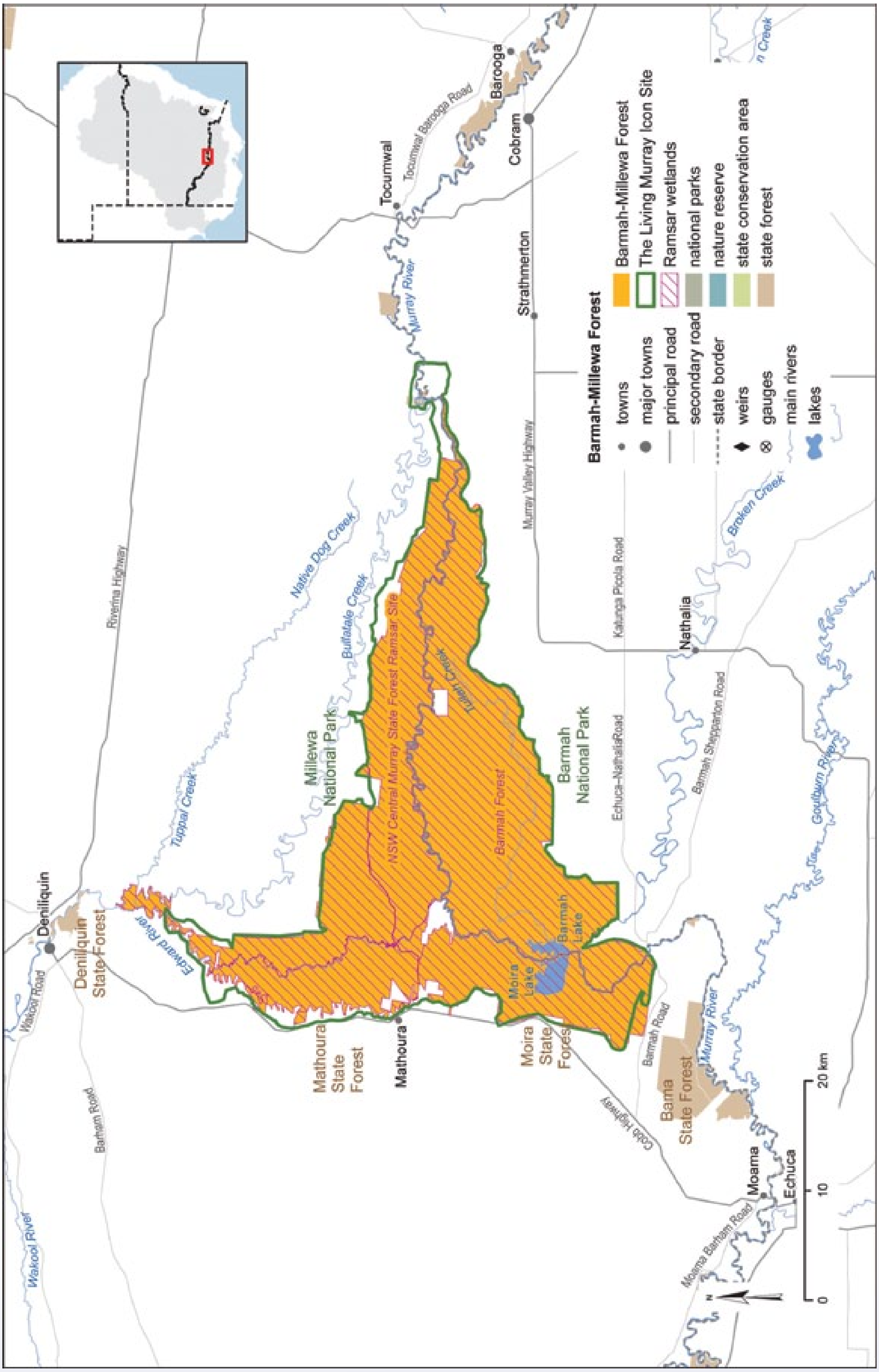

Figure 1: Location of Barmah-Millewa forest (MDBA 2010a).

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.

Ecological objectives	Extreme Dry Avoid damage to key environmental assets	Dry Ensure ecological capacity for recovery	Median Maintain ecological health and resilience	Wet Improve and extend healthy and resilient aquatic ecosystems
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.

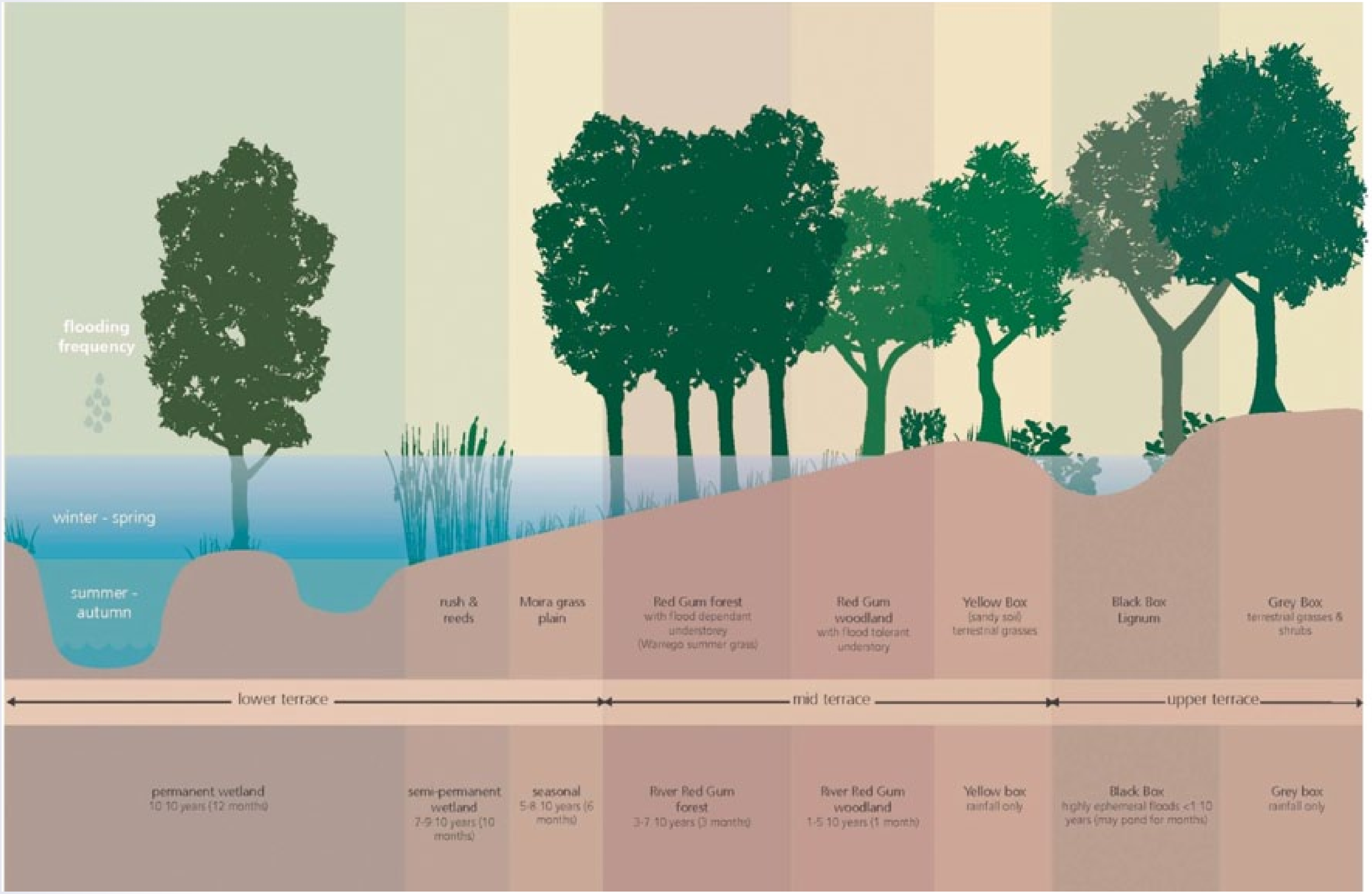

Figure 2: Cross-section of the Barmah-Millewa floodplain showing key vegetation communities and their water requirements (MDBA in prep).

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.

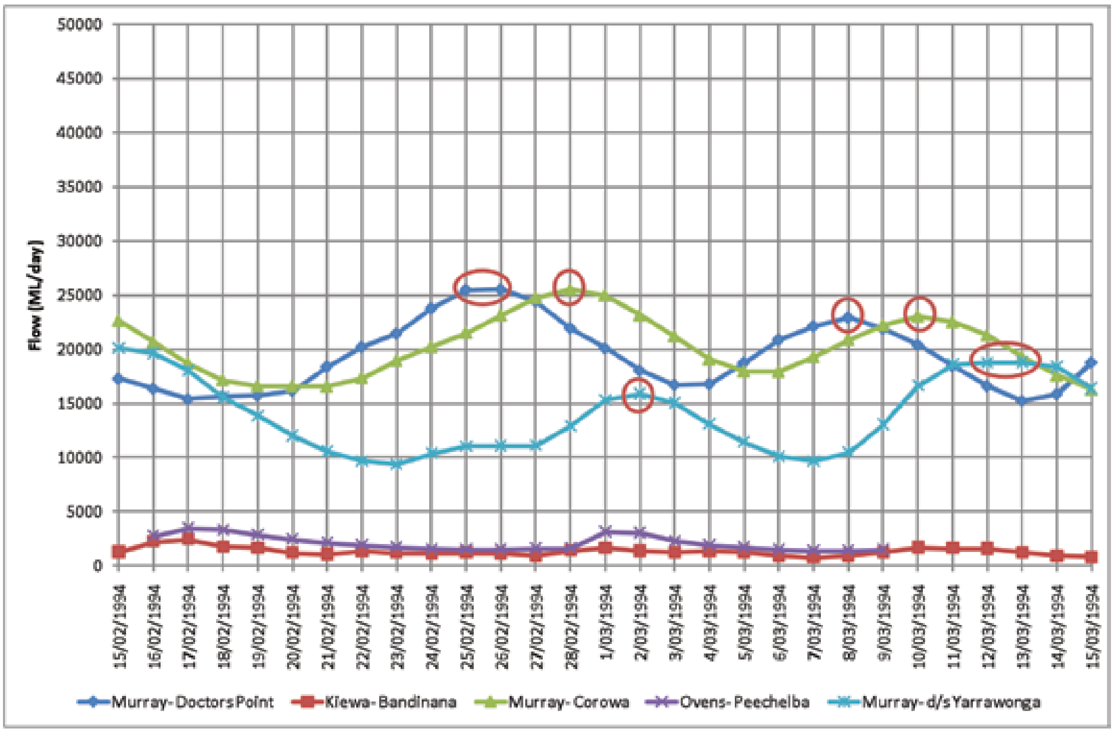

Figure 3: Travel time from Hume Dam to d/s Yarrawonga (Feb–Mar 1994 event, 10–20,000 ML/d d/s of Yarrawonga).

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.

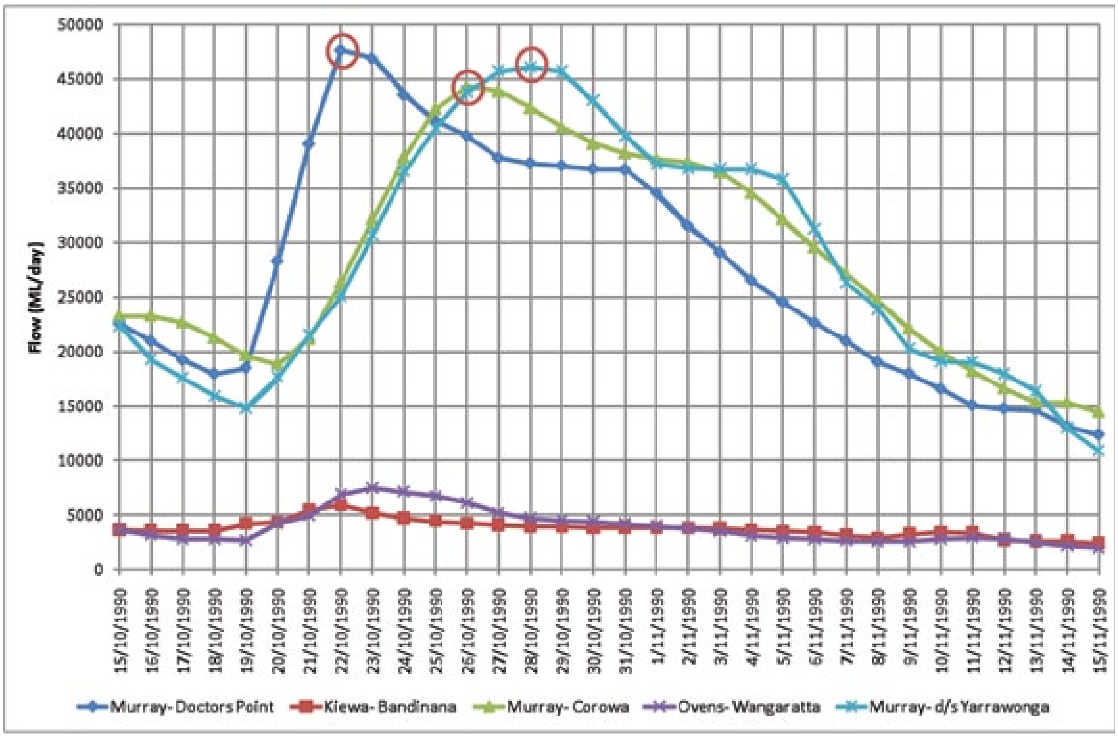

Figure 4: Travel time from Hume Dam to d/s Yarrawonga (Oct–Nov 1990 event, 45,000 ML/d d/s Yarrawonga).

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.

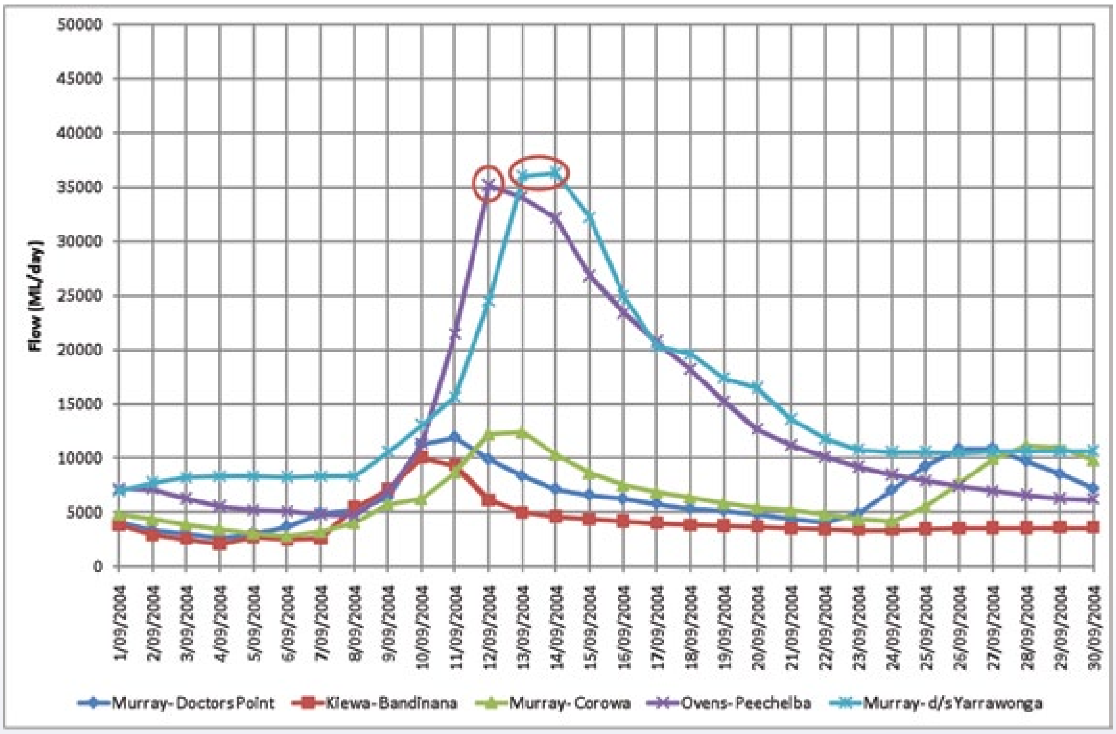

Figure 5: Travel time from Peechelba to d/s Yarrawonga (Sep 2004 event, 35,000 ML/d d/s Yarrawonga).

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.

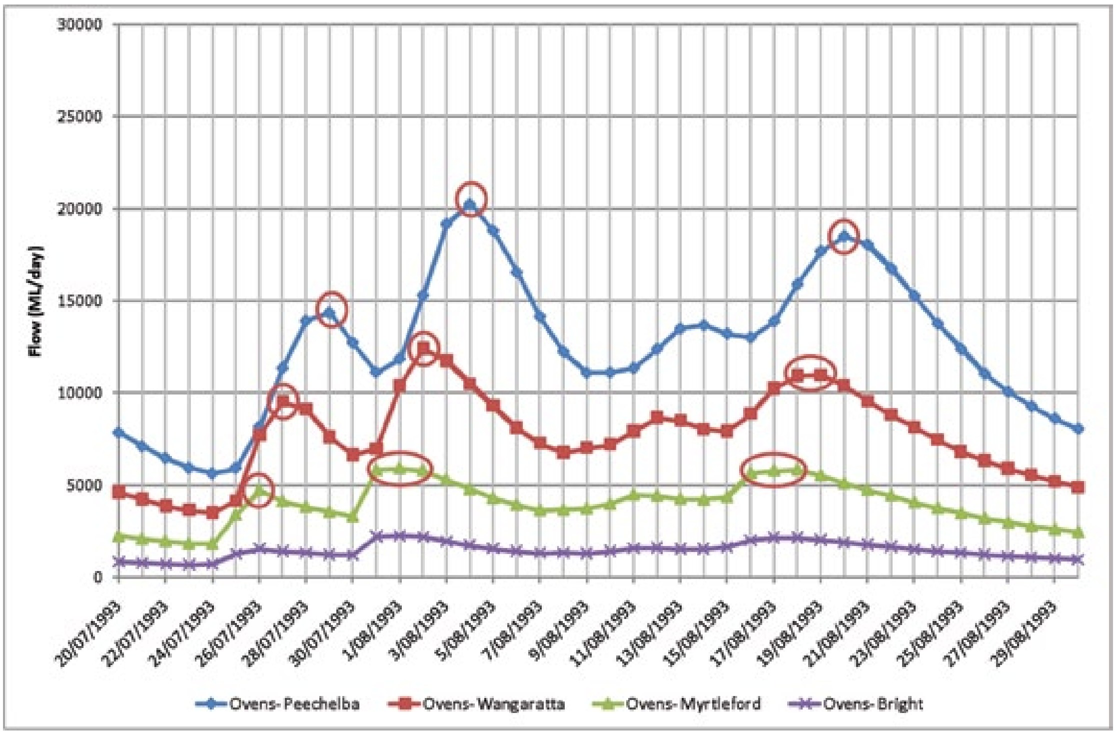

Figure 6: Travel time along the Ovens River (Jul–Aug 1993 events, 15–20,000 ML/d at Peechelba).

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.

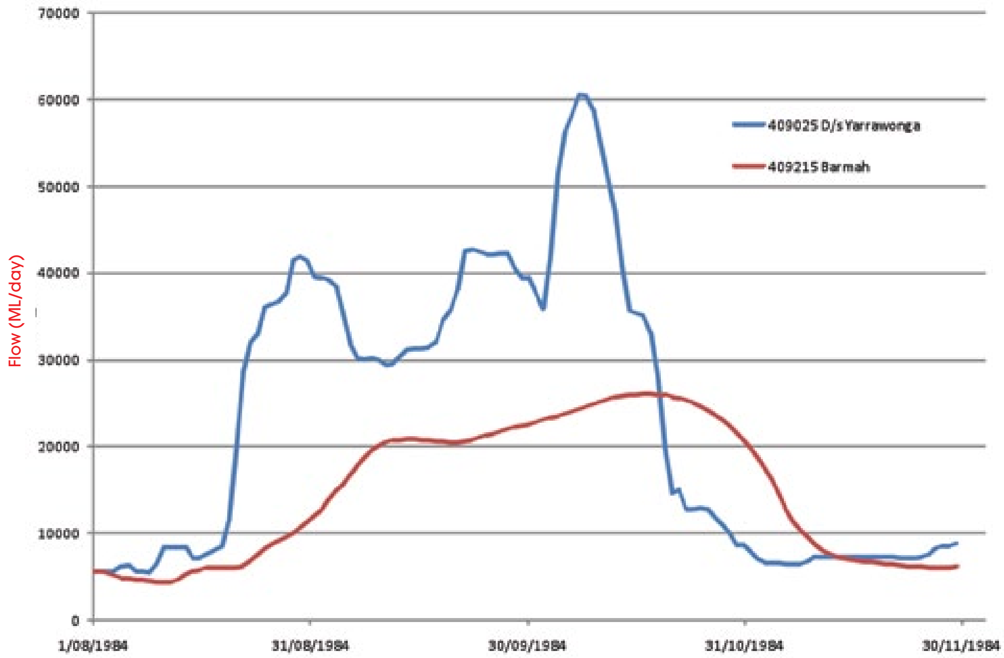

Figure 7: Travel time from Yarrawonga to Barmah (Aug–Oct 1984 events, 30–60,000 ML/d d/s Yarrawonga).

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).

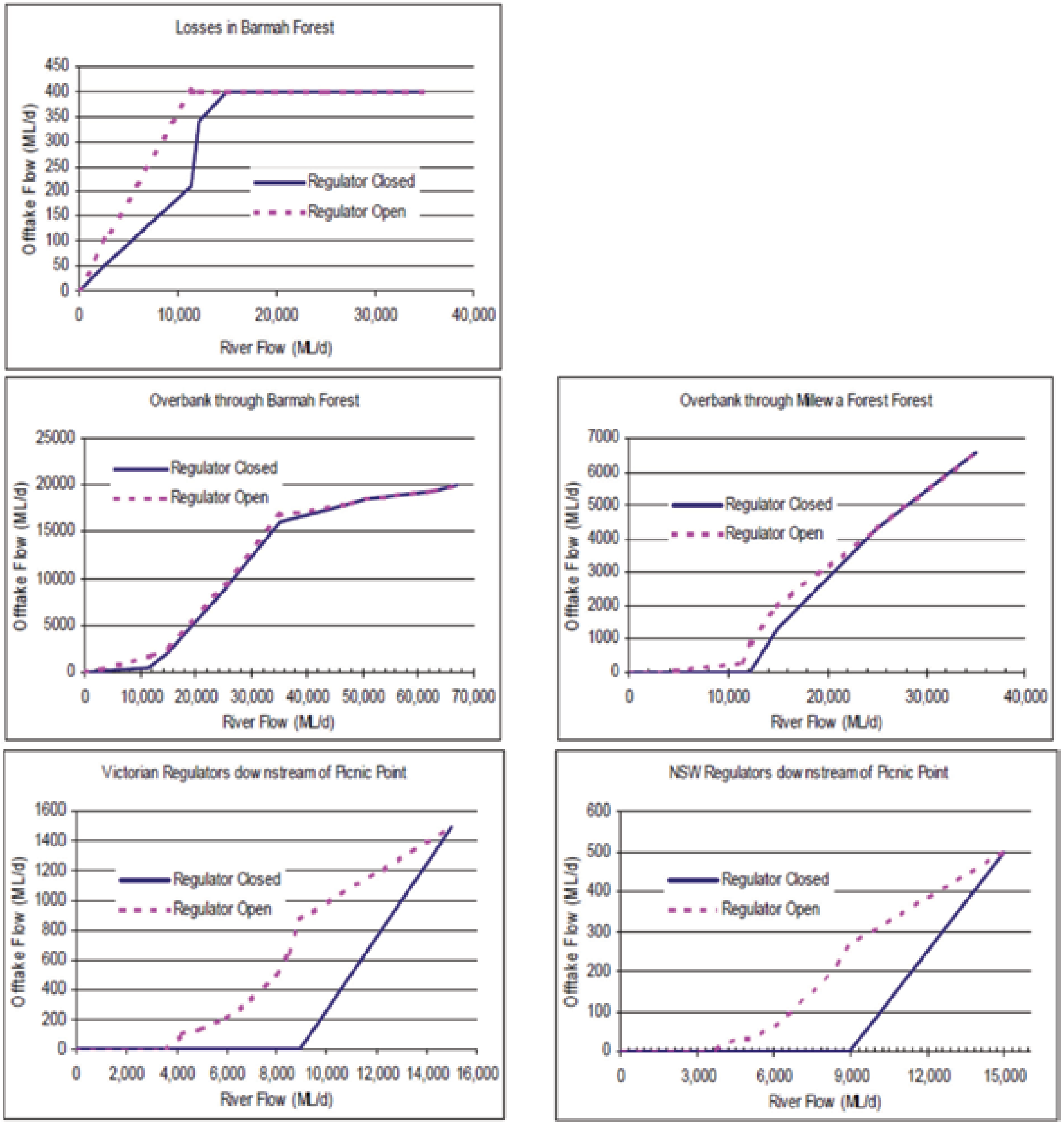

Figure 8: Loss and overbank flows through Barmah-Millewa forest in MSM-Bigmod (MDBC 2002).

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.

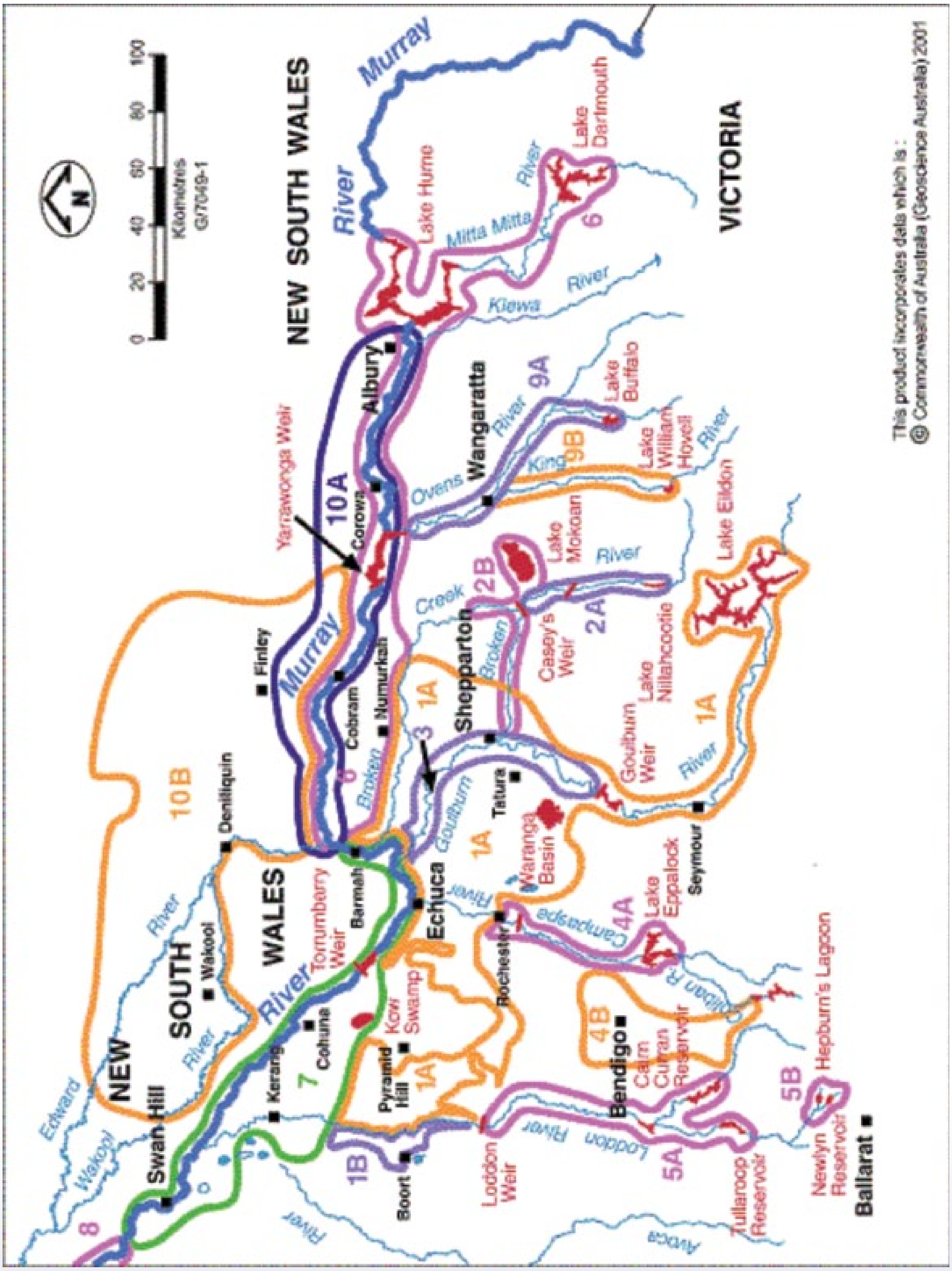

Figure 9: Trading zone boundaries (http://www.watermove.com.au).

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.

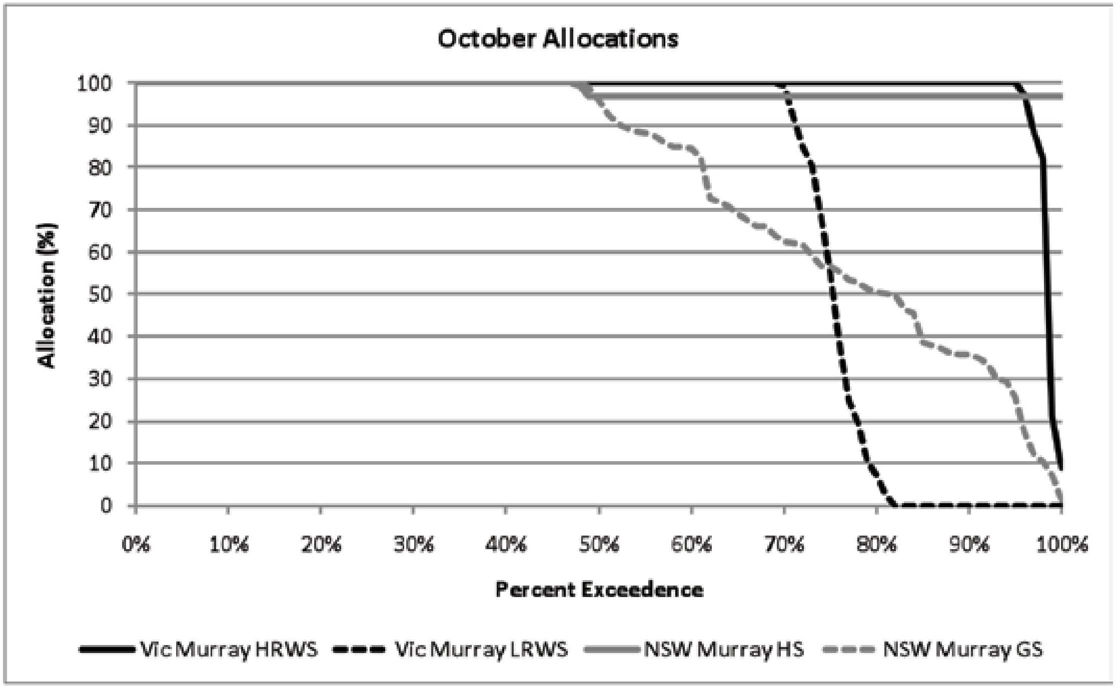

Figure 10: October seasonal allocations for the Murray system.

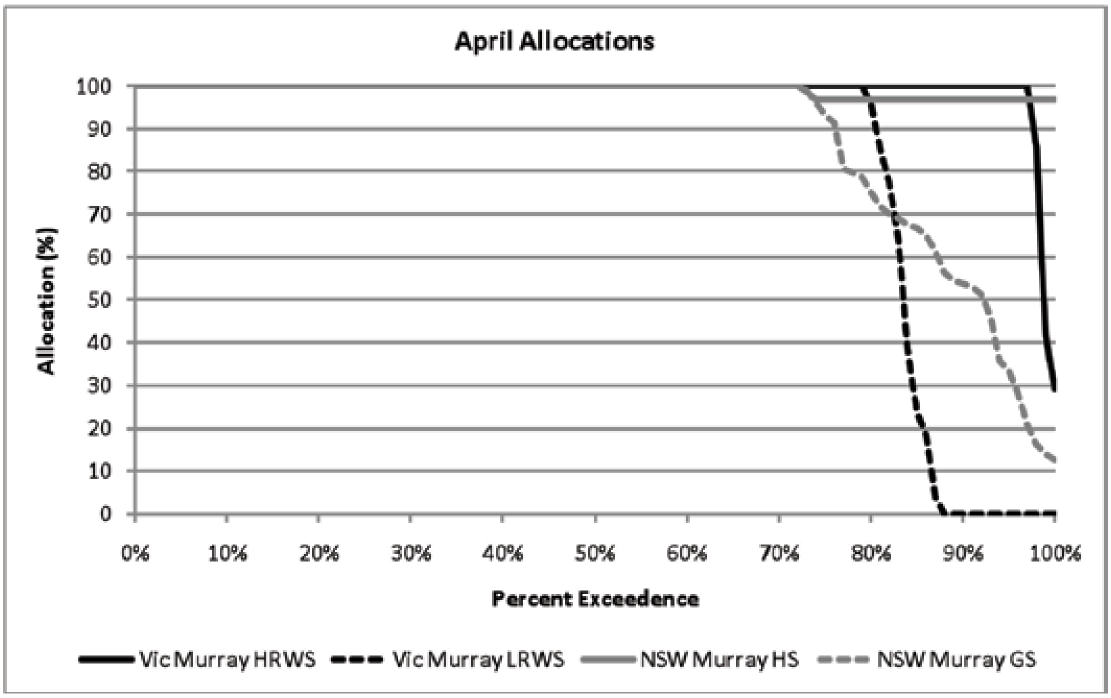

Figure 11: April seasonal allocations for the Murray system.

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).

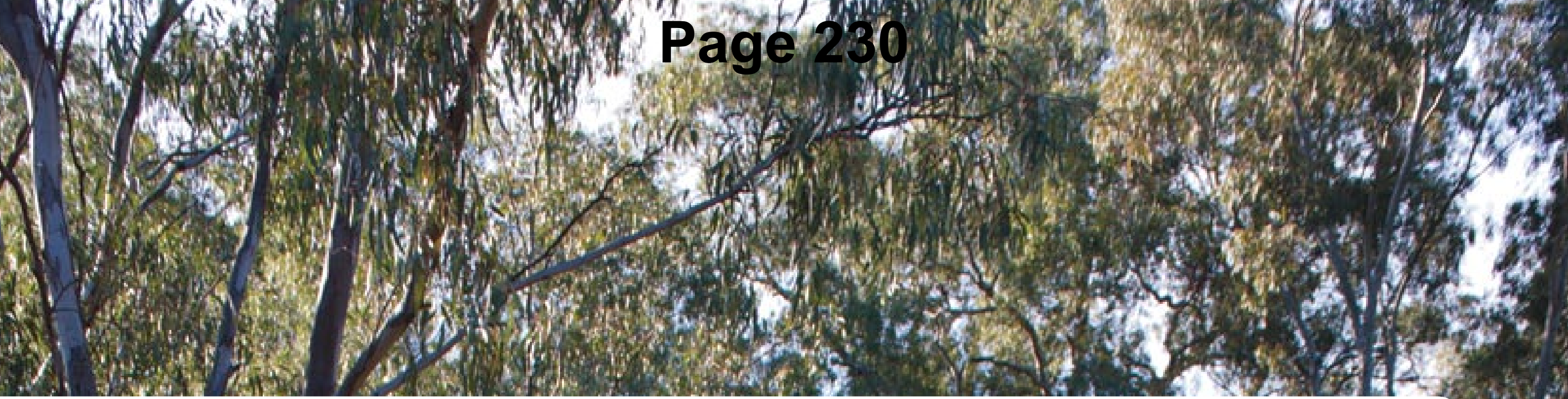
2 For internal use. Permission will be sought before any public use.

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



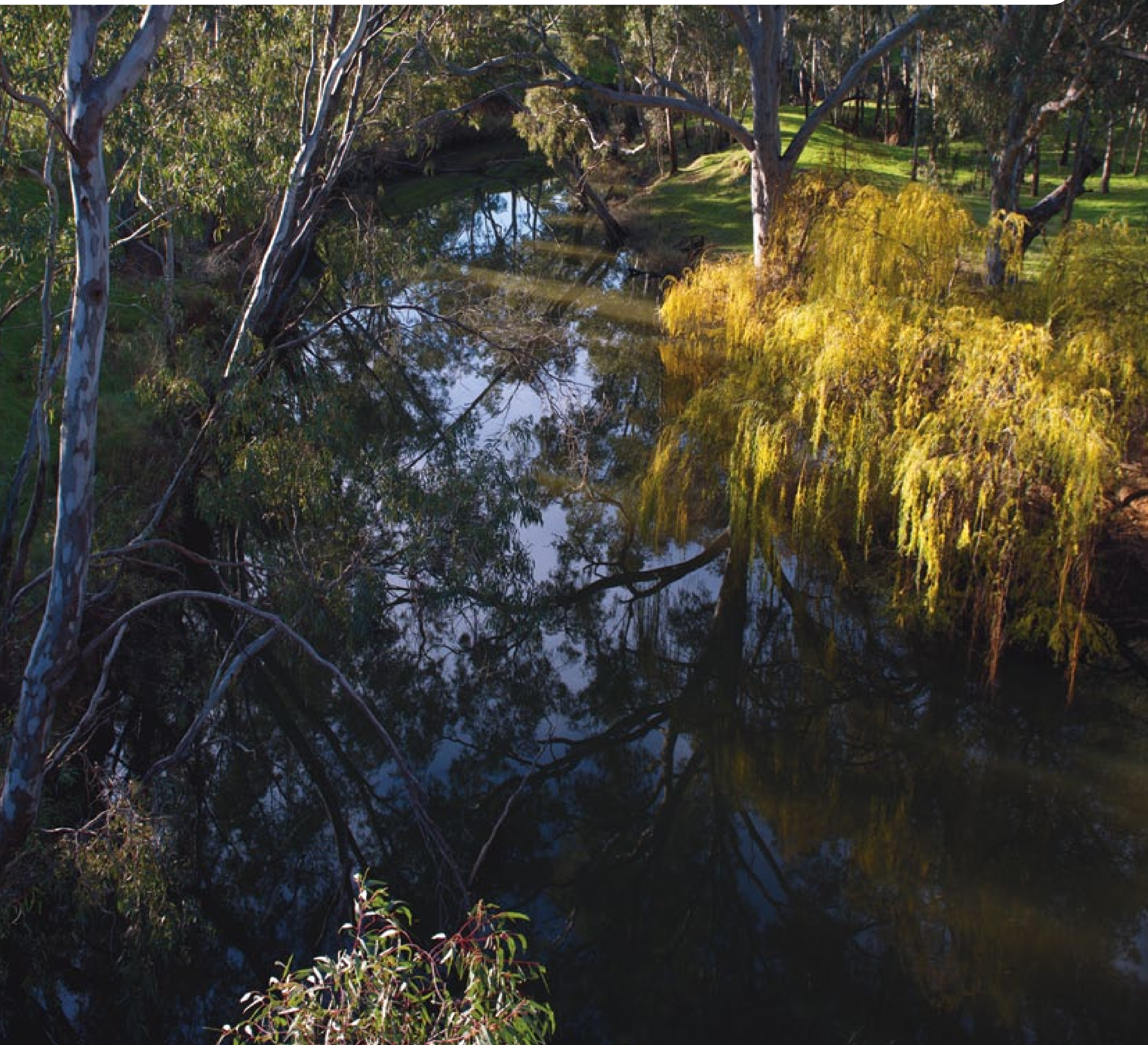
Australian Government

Commonwealth Environmental Water

ENVIRONMENTAL WATER DELIVERY

CAMPASPE RIVER

AUGUST 2011 V1.0



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Peter Cottingham & Associates and SKM (2011). *Environmental Water Delivery: Campaspe River.* Prepared for Commonwealth Environmental Water, Department of Sustainability, Environment, Water, Population and Communities, Canberra.

ISBN: 978-1-921733-29-1

SEWPaC acknowledges the following individuals and organisations that have been consulted in the preparation of this document:

Michael Jensz (Department of Sustainability and Environment, Victoria)
Mark Bailey (Goulburn-Murray Water)
Andrew Shields (Goulburn-Murray Water)
Darren White (North Central Catchment Management Authority)
Geoff Earl (Goulburn Broken Catchment Management Authority)
Garry Smith (DG Consulting)
Ben Gawne (Murray-Darling Freshwater Research Centre)
Daren Barma (Barma Water Resources)
Murray-Darling Basin Authority

Published by the Commonwealth Environmental Water Holder for the Australian Government.

ENVIRONMENTAL WATER DELIVERY

CAMPASPE RIVER

AUGUST 2011 V1.0

Environmental Water Delivery: Campaspe River

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 Campaspe system.

The Campaspe River supports flora and fauna of national, regional and local conservation status and provides areas of important drought refugia. Potential water use options for the Campaspe system include the provision of winter and spring base flows to assist in maintaining habitat for native fish and invertebrates, sustaining river red gum recruitment and improving water quality. Outflows from the Campaspe are also expected to contribute to in-stream benefits downstream in the Murray River.

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, Goulburn-Murray Water, North Central Catchment Management Authority, Goulburn Broken 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.

Commonwealth Environmental Water
Department of Sustainability, Environment, Water, Population and Communities
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Acronyms

ACRONYM	MEANING
BE	Bulk entitlement
CEWH	Commonwealth Environmental Water Holder
COAG	Council of Australian Governments
DO	Dissolved oxygen
DPI	Victorian 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
eWater CRC	Environmental Water Co-operative Research Centre
EWRs	Environmental Water Holders
GBCL	Goulburn-Broken-Campaspe-Loddon
GB CMA	Goulburn Broken Catchment Management Authority
G-MW	Goulburn-Murray Water
IVTs	Inter-valley transfers
MDBA	Murray-Darling Basin Authority
NC CMA	North Central Catchment Management Authority
NERWMP	North East Regional Water Monitoring Partnership
RHS	North Central River Health Strategy
NRSWS	The Northern Region Sustainable Water Strategy
NVIRP	Northern Victoria Irrigation Renewal Project
SEWPaC	Australian Government Department of Sustainability, Environment, Water, Population and Communities
VEFMAP	The Victorian Environmental Flows Monitoring and Assessment Program
VEWH	Victorian Environmental Water Holder
VWQMN	Victorian Water Quality Monitoring Network

PART 1:
Management Aims

1. Overview

1.1 Scope and purpose of this document

Information provided 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 water use options for large volumes of environmental water.

To maximise the systems' 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.

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 options have been developed for each asset to meet watering objectives under a range of volume scenarios. Use of environmental water will aim to maximise environmental outcomes at multiple assets, where possible. In the first instance, water use strategies will provide an "event ready" basis for the use of Commonwealth environmental water. These strategies will be integrated into a five-year water delivery program.
3. Processes and mechanisms that are required to operationalise environmental water use strategies are documented and include such things as:
   - delivery arrangements and operating procedures
   - water delivery accounting methods that are either currently in operation at each asset 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.

Information provided in this document focuses on the environmental watering objectives and water use strategy for the regulated Campaspe River system in northern Victoria. This includes options for the use of water held in the Campaspe system, as well as options that might be pursued with access to environmental water held in the Goulburn system.

1.2 Catchment and river system overview

The Campaspe River catchment covers approximately 4,000 km^2 and extends for 150 km from the northern slopes of the Great Dividing Range near Trentham to the Murray River at Echuca. The Campaspe River and Coliban River are the largest rivers in the catchment, but other significant tributaries include Axe, McIvor, Mt Pleasant, Forest, Wild Duck and Pipers Creeks (SKM 2006).

Prior to agricultural development and river regulation, streams in the middle and lower Campaspe River catchment would have had low energy, contained fine grained sediments and had occasional rocky outcrops. Most of the streams would have had incised channels, with deep pools, infrequent riffles over gravel, boulders or logs and an abundance of large woody debris (North Central CMA 2005). Flows would have been seasonally variable, with high flows in winter and spring, and low or no flow in summer and autumn. However, the construction of reservoirs and weirs for potable supply and irrigation has substantially reduced flows throughout the catchment and altered the seasonal flow patterns in the lower reaches.

The Campaspe system is heavily regulated to supply water to meet irrigation, stock and domestic and urban demands. The hydrological regime of the Campaspe River has changed markedly since the construction and operation of Lake Eppalock, and releases for irrigation have substantially reversed seasonal flow patterns in the Campaspe River (SKM 2006). Significant storages on the Coliban River include Malmsbury (12,000 ML capacity), Lauriston (20,000 ML capacity) and Upper Coliban (38,000 ML capacity). Lake Eppalock (305,000 ML capacity) and Campaspe Weir (3,000 ML capacity) are the major storages on the Campaspe River. The Waranga Western Main Channel, which is a major carrier channel for the Goulburn system, passes through the Campaspe system and crosses underneath the Campaspe River downstream of Rochester at the Campaspe Siphon.

The regulated sections of the Campaspe system include four main reaches (Figure 1):

Reach 1. Coliban River: Malmsbury Reservoir to Lake Eppalock.
Reach 2. Campaspe River: Lake Eppalock to Campaspe Weir.
Reach 3. Campaspe River: Campaspe Weir to Campaspe Siphon.
Reach 4. Campaspe River: Campaspe Siphon to Murray River.

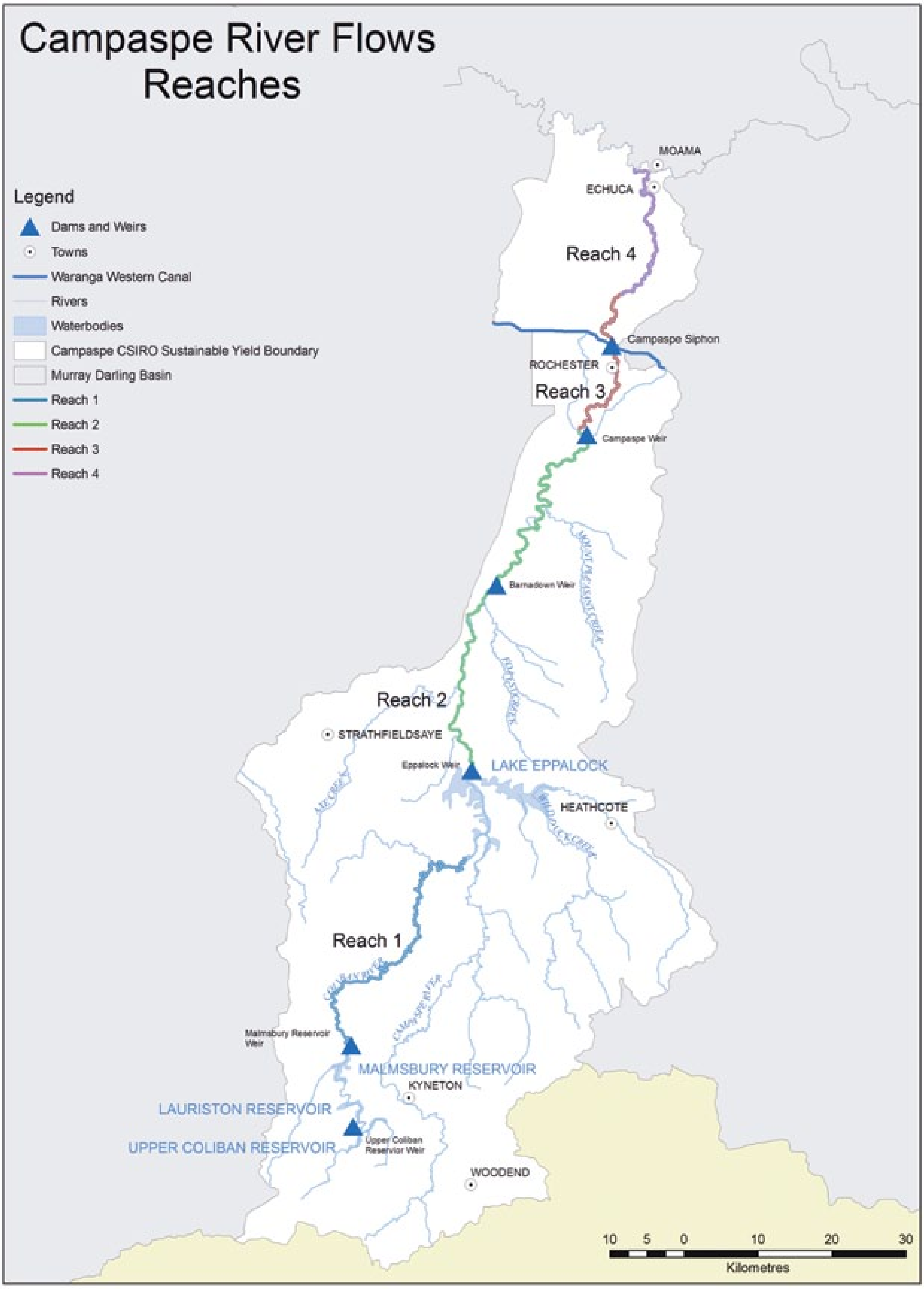

Figure 1: Regulated reaches of the Campaspe River (SEWPaC 2011).

The Campaspe River catchment, and the communities that rely on it for water supply, lies within a number of local government areas. These include Campaspe Shire, City of Greater Bendigo, Macedon Ranges Shire and Mitchell Shire. Land tenure along the Campaspe River is a mixture of conservation reserve and freehold. Intensive horticulture occurs in the upper catchment and mixed farming and cereal growing dominates the mid and lower catchment. Land use along the river is predominantly:

- conservation and natural environments (nature conservation, managed resource protection)
- grazed native vegetation
- production from dryland agriculture and plantations (grazing modified pastures, cropping)
- production from irrigated agriculture and plantations (irrigated modified pastures, irrigated perennial horticulture)
- intensive uses (residential, services).

1.3 Overview of river operating environment

Environmental water is managed by the Victorian Environmental Water Holder (VEWH) and the North Central Catchment Management Authority (NC CMA) in cooperation with the Victorian Department of Sustainability and Environment (DSE) and Goulburn-Murray Water (G-MW). G-MW manages river operations, with the exception of the urban water storages above Lake Eppalock. These storages, which include Upper Coliban, Lauriston and Malmsbury Reservoirs, are managed by Coliban Water, who is responsible for the majority of urban water supply in the Campaspe region. Coliban Water supplies the town of Bendigo via the Eppalock pipeline and the Coliban Main Channel. The Coliban Main Channel also supplies rural customers. Western Water manages small urban water storages in the upper Campaspe River catchment to supply customers south of the Great Dividing Range. G-MW is responsible for managing groundwater and surface water licensed private diversions from the Campaspe catchment.

The surface water resources of the Campaspe catchment are covered by bulk entitlements for water allocation from regulated streams (the Coliban River upstream of Eppalock and the Campaspe River downstream of Eppalock) and for all urban water use. Lake Eppalock storage capacity and inflow is shared between G-MW and Coliban Water on an 82:18 basis when the storage is at full supply level (CSIRO 2008). There are private diverter licences in unregulated rivers of the catchment.

There were 64,700 ML of bulk entitlement and 4,700 ML of private diversion licences from unregulated streams within the region in 2005–06 (CSIRO 2008). The environmental water reserve for the Campaspe region includes passing flows released as a condition of consumptive bulk entitlements held by Coliban Water, Western Water and G-MW. Approximately 56 per cent of the surface water resource in the Campaspe is not diverted in an average year and provides environmental flows according to the prescribed rules for passing flow requirements (CSIRO 2008). Passing flows are prescribed for three of the four main reaches of the Campaspe system:

- Coliban River downstream of Malmsbury Reservoir (Reach 1).
- Campaspe River between Lake Eppalock and Campaspe Weir (Reach 2).
- Campaspe River between the Siphon and the Murray River (Reach 4).

Commonwealth environmental water holdings currently include entitlements to water shares that are allocated water based on volumes stored in Lake Eppalock, and not the Upper Coliban storages. Therefore the Coliban River is not considered in subsequent sections of this document.

The Waranga Western Main Channel, which carries water from the Goulburn River to supply irrigation districts to the west, does not directly intersect the Campaspe River as water passes underneath the Campaspe River via a siphon located a short distance downstream of Campaspe Weir. The Campaspe River can interact with the Waranga Western Main Channel by providing a supplement to the Goulburn system in wet years via the Campaspe pumps, and the Waranga Western Main Channel can outfall to the Campaspe River downstream of Rochester.

Campaspe Weir regulates flow into the distribution network of the Campaspe Irrigation District. The Campaspe Irrigation District is due to be decommissioned as a part of the Northern Victorian Irrigation Renewal Project (NVIRP), which could change river operations in the Campaspe River.

2. Ecological values, processes and objectives

2.1 Summary of ecosystem values

The Campaspe River supports flora and fauna of national, regional and local conservation significance (SKM 2006b, North Central CMA 2005, 2010, Appendix 1). For example, 11 fish species, including five of significant conservation status, have been recorded in the Campaspe River below Lake Eppalock over the past 30 years (SKM 2006b). Four threatened plant species have been recorded among the 11 significant Ecological Vegetation Classes (EVCs) along Reach 4 (North Central CMA 2009). Features such as pools (including weir pools such as Campaspe Weir and The Siphon) serve as important refugia for the survival of organisms that can recolonise reaches following periods of drought. Protecting and then connecting in-channel habitat is important for the recovery of the river following periods of cease-to-flow.

In addition, the Campaspe River connects to the Murray River, providing important ecological links and biodiversity in a region and landscape that has been heavily modified. Water discharged from the Campaspe River can, along with water from the Goulburn River, contribute to watering environmental assets downstream along the Murray River.

The Campaspe River is considered a high priority under the North Central Regional River Health Strategy (RHS) (North Central CMA 2005). A major objective of the RHS is to focus on the high values within reaches considered to be at high risk and implement mitigation actions. Reach 4 downstream of Campaspe Siphon is a priority under the RHS in order to:

- Minimise the risks to connected high value assets (Murray River). The lower Campaspe River can significantly influence the health of the Murray River.
- Protect and enhance reaches at high risk – this reach is ranked in the top 20 high risk reaches in the RHS.

Given the above, over-arching objectives set for the Campaspe River are summarised in Table 1.

Table 1: General ecological objectives for targeted water use (SKM 2006).

Water management area	Broad scale system objective	Ecological Objectives
Reach 2: Campaspe River from Lake Eppalock to Campaspe Weir.	In summary, the objectives are: • maintain current channel geometry • rehabilitate the native fish community through improved conditions for recruitment, maintenance and movement • reduce nutrient concentrations and salinity and improve dissolved oxygen concentrations • rehabilitate riparian vegetation and increase diversity of instream vegetation.	The objectives are to: • maintain current channel hydraulic geometry • rehabilitate riparian vegetation extent, structure and composition and increase diversity of instream vegetation • rehabilitate native fish community through improved conditions for recruitment, maintenance and movement • reduce nutrient concentrations and salinity downstream of Axe Creek and reduce temperature impacts downstream of Lake Eppalock • maintain current macroinvertebrate community diversity in edge habitats, increase diversity of riffle dwelling species, increase abundance of pollution sensitive taxa and reduce effect of temperature impacts downstream of Lake Eppalock.
Reach 4: Campaspe River from The Siphon to the Murray River.	• As above.	The objectives are to: • maintain current channel hydraulic geometry • rehabilitate riparian vegetation extent, structure and composition, inundate and drain wetlands, and increase diversity of instream vegetation • rehabilitate the native fish community through improved conditions for recruitment, maintenance and movement and link to Murray River fish communities • reduce salinity and improve dissolved oxygen throughout the Reach • increase macroinvertebrate diversity, especially pollution sensitive taxa.

More detailed objectives are presented in Section 3.1.

3. Watering objectives

3.1 Broad-scale ecosystem objectives

3.1.1 Murray-Darling Basin

Work being undertaken by the Murray-Darling Basin Authority (MDBA 2010) follows a number of broad objectives, the following of which are relevant when considering options for the use of environmental water:

- maintain and improve the ecological health of the Basin, and in doing so optimise the social, cultural, and economic wellbeing of Basin communities
- improve the resilience of key environmental assets, water-dependent ecosystems and biodiversity in the face of threats and risks that may arise in a changing environment
- maintain appropriate water quality, including salinity levels, for environmental, social, cultural and economic activity in the Basin.

These, and flow-related ecological objectives stated in environmental flow studies (SKM 2006) and negotiated as part of the Northern Regional Sustainable Water Strategy (NRSWS) (DSE 2009), are important considerations when allocating environmental water in the Campaspe system. Importantly, the development of the NRSWS has resulted in agreement that overbank flows along Reach 4 cannot be included in flow-related objectives for this reach of the Campaspe River.

Environmental watering objectives were specified for the Campaspe River (SKM 2006) when developing environmental flow recommendations for the river. The general environmental watering objectives were to:

- maintain current channel geometry
- rehabilitate the native fish community through improved conditions for recruitment, maintenance and movement
- reduce nutrient concentrations and salinity and improve dissolved oxygen concentrations
- rehabilitate riparian vegetation and increase diversity of instream vegetation.

3.2 Proposed asset watering objectives

Environmental watering objectives for the Campaspe River (SKM 2006) are presented in Tables 2 and 3. They are based on the watering needs of Reaches 2, 3 and 4, with priority given to Reach 4, which has greater environmental values (DSE 2009). There are no specific overbank flow recommendations for Reach 4, but meeting environmental flow recommendations for high flows will result in minor overbank flows at some points along Reach 2. Meeting the flow requirements for Reach 4 will also meet the needs of Reach 3. The environmental flows proposed to meet the objectives outlined in Table 2 and Table 3 are presented in Section 3.3.

It should be noted that the scenarios for extreme dry, dry, median and wet years identified in Table 1 are only indicative of what might occur. Such categorisations infer that a particular year remains constant (i.e. a dry year remains dry) and independent from other scenarios. In reality, climatic and flow conditions can vary seasonally and annually, as well as interact. For example, a dry spring may be followed by a wet summer, with water availability being that of a median year overall. Climatically, conditions may be dry or very dry, but because of water demand and delivery, flow conditions in a river may be that of a median or wet year.

Table 2: Summary of proposed environmental watering objectives and anticipated outcomes for Reach 2 of the Campaspe River (based on SKM 2006).

Asset	Objective	Function	Flow component	Timing	Anticipated outcome
Geomorphology	Maintain current channel hydraulic geometry.	Channel forming processes.	Bankfull	Winter	• Maintain current channel form.
		Provide lateral connection to flood runners.	Overbank	Winter	
Vegetation	Rehabilitate riparian vegetation extent, structure and composition and increase diversity of instream vegetation.	Maintain aquatic vegetation.	Low flow	Summer	• Winter and spring flows will facilitate the recruitment of native riparian species such as river red gum, but summer freshes will be required to water these recruits to ensure their survival and growth. Some areas of the channel have excessive *Typha spp.* growth, which should be scoured by bankfull flows.
		Maintain riparian and in channel recruits.	Fresh	Summer	
		Reduce encroachment of exotics and terrestrial species.	Fresh	Winter	
		Enhance river red gum recruitment.	High flow	Winter	
		Scour *Typha spp.* from middle of channel.	Bankfull	Winter	
		Enhance river red gum recruitment.	Overbank	Winter	
Fish	Rehabilitate native fish community through improved conditions for recruitment, maintenance and movement.	Increase food concentration for fish larvae and juveniles.	Cease to flow	Summer	• No decline in native fish diversity and abundance – possible increase in native fish recruitment due to reinstatement of slackwaters and some movement of species between Reaches.
		Maintain habitat and re-instate slackwaters.	Low flow	Summer	
		Provide longitudinal connectivity during low flow period.	Fresh	Summer	
		Provide longitudinal connectivity.	Low flow	Winter	
		Cue fish movement and allow movement to downstream Reaches.	High flow / Bankfull	Winter	
		Limit effect of cold water releases.	Complementary	As part of release operations	

Asset	Objective	Function	Flow component	Timing	Anticipated outcome
Water quality	Reduce nutrient concentrations and salinity downstream of Axe Creek and reduce temperature impacts downstream of Lake Eppalock. Water quality objectives can be achieved through targeted action or as secondary benefits resulting from other watering actions.	Maintain permanent connecting flow.	Low flow	Summer / winter	• Improvements in water quality are likely to result in positive ecological responses from fauna and flora. Specifically, native fish and sensitive plant species will be supported by improved water quality. Improved water quality will result in overall improved health of the asset. • As winter flows are currently much lower than natural, increasing winter flows will help dilute inputs from Axe Creek and reduce stratification in deep pools. • Winter high flows will mix and flush deep pools downstream of Axe Creek and reduce salt, temperature and oxygen stratification. High flows will only be effective if low flows at other times are sufficient otherwise pools will restratify.
		Flush and mix pools.	High Flows	Winter	
		Limit effect of cold water releases.	Complementary	As part of release operations	• Temperature impacts downstream of Lake Eppalock should be managed by adjusting the water release level. This may be feasible given that Lake Eppalock already has a multi-level offtake tower.
Macroinvertebrates	Maintain current macroinvertebrate community diversity in edge habitats, increase diversity of riffle dwelling species, increase abundance of pollution sensitive taxa and reduce effect of temperature impacts downstream of Lake Eppalock.	Maintain access to riffle habitat and maintain water quality.	Low flow	Summer / winter	• Summer and winter low flows that maintain permanent riffle habitats combined with gradual flow changes will increase the abundance and diversity of riffle dwelling species. • Improved water quality will help maintain macroinvertebrate diversity and increase the abundance and diversity of pollution sensitive taxa, which will increase the SIGNAL score for this reach particularly downstream of Axe and Mt Pleasant Creeks. • Reduced temperature impacts downstream of Lake Eppalock will increase growth rates and help synchronise development times for macroinvertebrates including *Macrobrachium sp.*
		Prevent sudden changes in flow.	Ramp flows up and down	As required	
		Flush and mix pools.	High Flows	Winter	
		Limit effect of cold water releases.	Complementary	As part of release operations	

Table 3: Summary of proposed environmental watering objectives and anticipated outcomes for Reaches 3 and 4 (based on SKM 2006).

Asset	Objective	Function	Flow component	Timing	Expected response
Geomorphology	Maintain current channel hydraulic geometry.	Channel forming processes.	Bankfull	Winter	• Maintain current channel form.
Vegetation	Rehabilitate riparian vegetation extent, structure and composition, inundate and drain wetlands, and increase diversity of instream vegetation.	Maintain aquatic vegetation.	Low flow	Summer	• Winter and spring flows will facilitate the recruitment of native riparian species such as river red gum, but summer freshes will be required to water these recruits to ensure their survival and growth. Some areas of the channel have excessive *Typha spp.* growth, which would be scoured by bankfull flows.
		Maintain riparian and in channel recruits.	Fresh	Summer	
		Reduce encroachment of exotics and terrestrial species.	Fresh	Winter	
		Enhance river red gum recruitment.	High flow	Winter	
		Scour *Typha spp.* from middle of channel.	Bankfull	Winter	
Fish	Rehabilitate native fish community through improved conditions for recruitment, maintenance and movement and link to Murray River fish communities.	Maintain habitat and re-instate slackwaters.	Low flow	Summer	• No decline in native fish diversity and abundance – possible increase in native fish recruitment due to reinstatement of slackwaters and some movement of fish from upstream and Murray River.
		Provide longitudinal connectivity during low flow period and cue fish movement from the Murray River.	Fresh	Summer	
		Provide longitudinal connectivity.	Low flow	Winter	
		Cue fish movement and allow movement between upstream and downstream reaches.	High / Bankfull flow	Winter	
Water quality	Reduce salinity and improve dissolved oxygen throughout the Reach.	Maintain constant flow.	Low flow	Summer / winter	• Minimum low flows will need to be maintained throughout the year to prevent the formation of saline pools. Freshes can mix pools if stratification does occur, but without adequate low flows, saline pools can be expected to reform within two weeks.
		Flush and mix pools.	Freshes	Throughout year	
Macroinvertebrates	Increase macroinvertebrate diversity, especially pollution sensitive taxa.	Maintain aquatic habitat.	Low flow	Summer / winter	• Low flows and periodic freshes will maintain the quality and quantity of aquatic habitat, which will maintain the current macroinvertebrate community.
		Inundate additional snags and flush sediments off biofilms.	Freshes	Throughout year	• Periodic freshes will also inundate additional snag habitats that may be temporarily used by some species and will facilitate wetting and drying of biofilms, but will more importantly flush sediment from biofilms and therefore increase food availability for macroinvertebrates.

3.3 Summary of watering objectives

The Campaspe River is a highly regulated river system, with water released from Lake Eppalock to supply the Campaspe Irrigation District and the demands of private diverters in Reaches 2, 3 and 4. Flow in the Campaspe River is affected by the operation of Lake Eppalock, as well as Campaspe Weir and the Campaspe Siphon. This document focuses on the environmental watering needs of Reach 2 (Lake Eppalock to Campaspe Weir) and Reach 4 (Campaspe Siphon to the Murray River), as these Reaches contain the highest environmental values, and flows for these reaches are prescribed in the Campaspe Bulk Entitlement. The environmental flows recommended for Reaches 2, 3 and 4 are presented in Table 4 and Table 5.

Table 4: Proposed environmental flows for Reach 2 of the Campaspe River (SKM 2006).

Stream		Campaspe River		Reach	Lake Eppalock to Campaspe Weir	
Compliance point		Site 6 – Doakes Reserve		Gauge No.	406207	
Season	Component	Volume	Frequency	Duration	Rise	Fall
Summer	Cease to flow	0 ML/d	1 per year	14 days		
	Low flow	10 ML/d (or natural)	1 per year	6 months		
	Freshes	100 ML/d	3 per year (or natural)	5 days	230%	65%
Winter	Low flow	100 ML/d (or natural)	1 per year	6 months		
	High flow	1,000 ML/d	4 per year (or natural)	4 days	230%	65%
	Bankfull flow	10,000 ML/d	1 per year (or natural)	2 days	230%	65%
	Overbank flow	12,000 ML/d	1 per year	1 day	230%	65%

Table 5: Proposed environmental flows for Reaches 3 and 4 of the Campaspe River (SKM 2006).

Stream		Campaspe River		Reach	Campaspe Siphon to Murray River	
Compliance point		Site 2 – Strathallan		Gauge No.	406265	
Season	Component	Volume	Frequency	Duration	Rise	Fall
Summer	Low flow	10 ML/d (Not more than 20 ML/d*)	1 per year	6 months		
	Freshes	100 ML/d	3 per year (Feb to May**)	6 days	230%	65%
Winter	Low flow	200 ML/d (or natural)	1 per year	6 months		
	High flow	1,500 ML/d	2 per year (or natural)	4 days	230%	65%
	Bankfull flow	Reach 3: 8,000 ML/d Reach 4: 9,000 ML/d	2 per year (or natural)	2 days	230%	65%

* This value may be reviewed after planned work assessing behaviour of saline pools and slackwaters in different flow conditions has been completed.

** Additional freshes may be released between December and February to manage water quality if required.

Objectives and potential watering options for Reaches 2 and 4 using environmental water are presented in Table 6. Preference is given by the North Central CMA and VEWH to delivering all the proposed flow components to Reach 4 from Lake Eppalock, as this would result in a connected river and multi-use of releases through Reaches 2, 3 and 4 between Lake Eppalock and the Murray River.

Table 6: Summary of proposed environmental watering objectives for the Campaspe River.

	Management objectives for specific water availability scenarios			
	Extreme dry	Dry	Median	Wet
	Goal: Avoid damage to key ecological assets	Goal: Ensure ecological capacity for recovery	Goal: Maintain ecological health and resilience	Goal: Improve and extend healthy aquatic ecosystems
Water availability	Minimum inflows and allocation on record	30th percentile year	50th percentile year	70th percentile year
Campaspe River				
Reach 2	• Avoid critical loss of threatened species and communities (Murray cod). • Maintain key refuges (deep and shallow water habitat, connection between in-channel habitats). • Avoid irretrievable damage or catastrophic events (low DO events, fish kills) (North Central CMA 2010). • Maintain baseflows and water quality as far as is possible. North Central CMA priority is to deliver summer baseflow. Assuming there is sufficient water for this, environmental water could be used to: • Supplement summer baseflow if necessary. • Supplement winter baseflow (June–November, up to 120 ML/d).	• Reduce encroachment of exotic (weed) and terrestrial vegetation. • Sustain river red gum recruitment. • Support the survival and growth of threatened species (Murray cod). • Provide longitudinal connectivity for native fish. • Maintain diverse habitats. • Manage flows through pools to reduce nutrient concentration and salinity, maintaining habitat quality for fish and macroinvertebrates. • Minimum (BE) baseflows can be supplied with current water availability. Environmental water could be used to: • Supplement winter baseflow (up to 120 ML/d). • Deliver up to four high flow events (up to 1,000 ML/d).	• Reduce encroachment of exotic (weed) and terrestrial vegetation. • Sustain river red gum recruitment. • Support the survival and growth of threatened species (Murray cod). • Provide longitudinal connectivity for native fish. • Maintain diverse habitats. • Manage flows through pools to reduce nutrient concentration and salinity, maintaining habitat quality for fish and macroinvertebrates. • Minimum (BE) baseflows can be supplied with current water availability. • Water quality should also be maintained with current water availability. Environmental water could be used to: • Supplement winter baseflow (up to 120 ML/d). • Deliver up to four high flow events (up to 1,000 ML/d).	• Reduce encroachment of exotic (weed) and terrestrial vegetation; • Sustain river red gum recruitment. • Support the survival and growth of threatened species (Murray cod). • Provide longitudinal connectivity for native fish. • Maintain diverse habitats. • Manage flows through pools to reduce nutrient concentration and salinity, maintaining habitat quality for fish and macroinvertebrates. • The Campaspe River has experienced high flows in 2010 and some flooding. No further high flows are required for the next two years. Environmental water could be used to: • Supplement winter baseflow (up to 120 ML/d). • Deliver up to four high flow events (up to 1,000 ML/d).

	Management objectives for specific water availability scenarios			
	Extreme dry	Dry	Median	Wet
	Goal: Avoid damage to key ecological assets	Goal: Ensure ecological capacity for recovery	Goal: Maintain ecological health and resilience	Goal: Improve and extend healthy aquatic ecosystems
Water availability	Minimum inflows and allocation on record	30th percentile year	50th percentile year	70th percentile year
Reach 3 and 4	• Avoid critical loss of threatened species and communities (Murray cod). • Maintain key refuges (deep and shallow water habitat, connection between in-channel habitats). • Avoid irretrievable damage or catastrophic events (low DO events, fish kills) (North Central CMA 2010). • Maintain minimum baseflows and water quality. Environmental water could be used to: • Supplement summer/autumn baseflow if necessary. • Supplement winter baseflow (up to 200 ML/d).	• Reduce encroachment of exotic and terrestrial vegetation. • Sustain river red gum recruitment. • Support the survival and growth of threatened species (Murray cod). • Provide longitudinal connectivity for native fish. • Maintain diverse habitats. • Manage flows through pools to reduce nutrient concentration and salinity, maintaining habitat quality for fish and macroinvertebrates. • Minimum (BE) baseflows can be supplied with current water availability. Environmental water could be used to: • Supplement winter baseflow (up to 200 ML/d). • Deliver up to two high flow events (up to 1,500 ML/d).	• Reduce encroachment of exotic and terrestrial vegetation. • Sustain river red gum recruitment. • Support the survival and growth of threatened species (Murray cod). • Provide longitudinal connectivity for native fish. • Maintain diverse habitats. • Manage flows through pools to reduce nutrient concentration and salinity, maintaining habitat quality for fish and macroinvertebrates. • Minimum (BE) baseflows can be supplied with current water availability. • Water quality should also be maintained with current water availability. Environmental water could be used to: • Supplement winter baseflow (up to 200 ML/d). • Deliver up to two high flow events (up to 1,500 ML/d).	• Reduce encroachment of exotic and terrestrial vegetation. • Sustain river red gum recruitment. • Support the survival and growth of threatened species (Murray cod). • Provide longitudinal connectivity for native fish. • Maintain diverse habitats. • Manage flows through pools to reduce nutrient concentration and salinity, maintaining habitat quality for fish and macroinvertebrates. Environmental water could be used to: • Supplement winter baseflow (up to 200 ML/d). • Deliver up to two high flow events (up to 1,500 ML/d).

PART 2:
Water Use Strategy

4. Environmental water requirements

4.1 Baseline flow characteristics

The Campaspe catchment has been subjected to unprecedented dry conditions over several years from the late 1990s to 2010. This has been reflected in allocations of less than 40 per cent of high reliability water shares to Campaspe irrigators from 2004–05 to 2009–10, and zero allocation in 2006–07, 2008–09 and 2009–10. The drought conditions led to a Qualification of Rights and the development of Dry Flow Contingency Plans. From 2007 to 2009, the majority of water flowing from the Campaspe River to the Murray River was attributable to inter-valley trade delivered via the Waranga Western Main Channel, rather than regulated releases from Lake Eppalock or natural catchment inflows, as shown in Figure 2 (North Central CMA 2010).

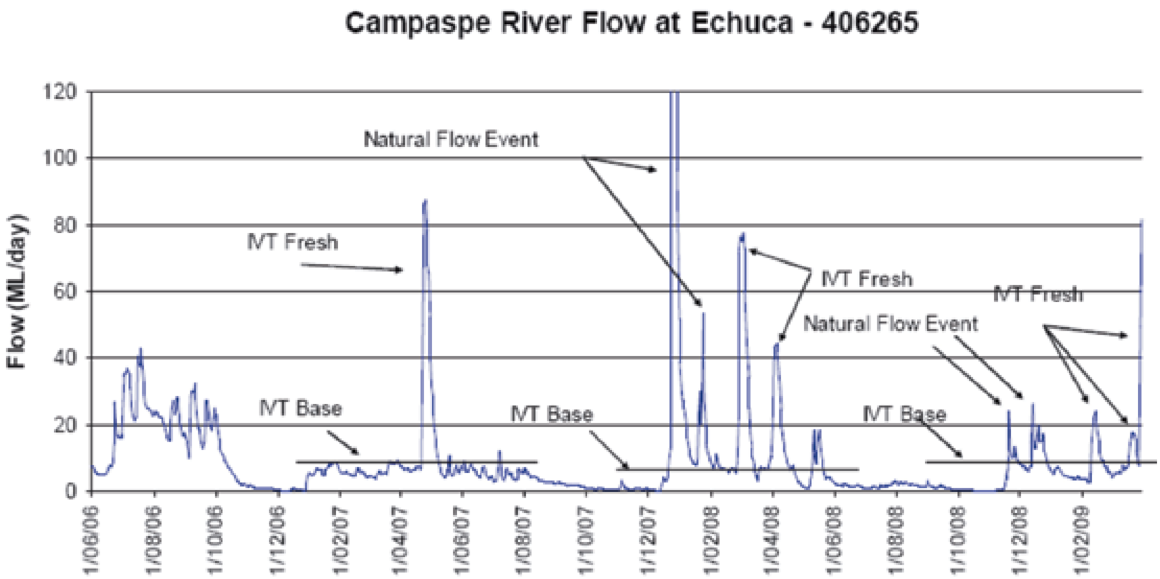

Figure 2: Flow in the Campaspe River at Echuca, and the contribution from inter valley trade (North Central CMA 2010).

The daily flow model of the Campaspe River is known as the Goulburn-Broken-Campaspe-Loddon REALM model. At the time of preparing this report, this model had not been updated for several years and many of the assumptions in the model were out of date. Hence gauged flow data has been used in the information presented below. Note that the values in Table 7 and Table 8 are derived independently for each month. In the very dry year in particular, the tables highlight that zero or very low flows can occur in each month of the year, but this does not necessarily mean that zero or very low flows persist for the whole year.

The period of data assessed in Table 7 and Table 8 is 1977 to 2010. This period of record includes a range of climatic conditions, including the recent drought conditions and the wetter conditions during the 1970s. It also includes many historical changes in operation, such as the introduction of minimum passing flows downstream of Lake Eppalock in G-MW's bulk entitlements.

For the Campaspe River at Barnadown (404201; Reach 2), flows during the summer irrigation season are much higher than natural (Figure 3), and there are low flows in winter unless Lake Eppalock is spilling (SKM 2006). For the Campaspe River at Rochester (404202; beginning of Reach 4), the natural seasonal flow pattern has been retained, but there are longer periods of low flow and shorter periods of high flow compared to natural (SKM 2006).

Table 7: Streamflows (ML/d) for the Campaspe River at Barnadown (1977–2009); Reach 2.

Month	Very dry year (minimum on record)	Dry year (30th percentile daily flow)	Median year (50th percentile daily flow)	Wet year (70th percentile daily flow)
Jul	0.2	20.8	36.2	76.9
Aug	1.5	39.9	79.3	349.0
Sep	0.1	89.1	190.5	828.4
Oct	4.3	162.0	274.0	579.0
Nov	2.6	192.0	275.0	342.0
Dec	8.7	228.0	289.5	348.7
Jan	0.0	220.3	309.0	360.0
Feb	7.8	215.9	327.0	459.0
Mar	7.2	185.3	456.5	742.0
Apr	1.2	81.5	144.0	209.0
May	2.4	22.5	35.0	66.8
Jun	0.0	13.5	19.5	30.0

Table 8: Streamflows (ML/d) for the Campaspe River at Rochester (1965–2009); beginning of Reach 4.

Month	Very dry year (minimum on record)	Dry year (30th percentile daily flow)	Median year (50th percentile daily flow)	Wet year (70th percentile daily flow)
Jul	0.5	20.1	35.0	76.1
Aug	0.0	23.3	56.6	392.2
Sep	0.0	24.9	87.7	1050.0
Oct	0.0	21.3	55.1	333.0
Nov	0.0	16.3	32.5	83.0
Dec	0.0	14.7	23.2	47.6
Jan	0.0	13.3	22.2	43.1
Feb	0.0	14.3	24.3	48.8
Mar	0.0	16.1	29.8	56.2
Apr	0.0	16.4	28.2	61.0
May	0.0	18.5	33.9	71.0
Jun	0.0	20.0	29.3	42.4

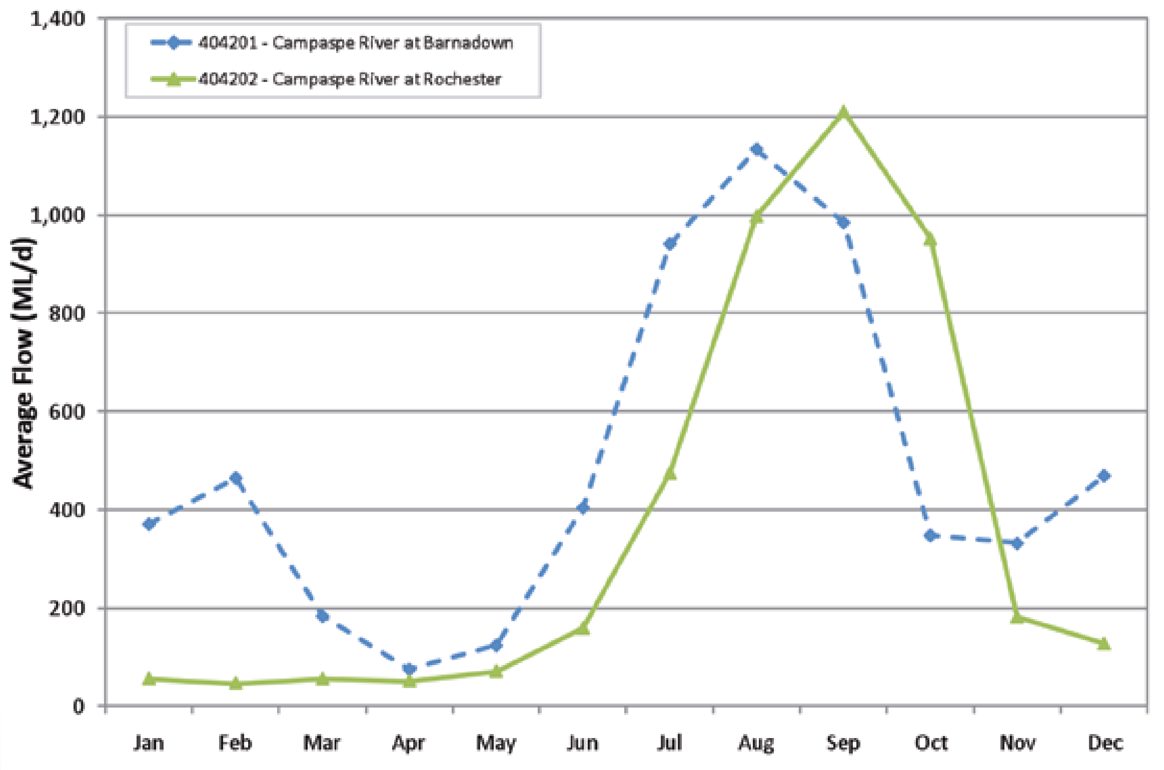

Figure 3: Average daily flow recorded at streamflow gauges at Barnadown (404201) and Rochester (404202) between 1977 and 2009.

4.2 Environmental water demands

Section 3.3 (Table 4) recommends a winter baseflow in all years of 120 ML/d or natural for Reach 2 and 200 ML/d or natural for Reach 4, and winter high flows in dry, median and wet years (Table 5). Based on these environmental water requirements, and winter flows through Reach 2 and Reach 4 of the Campaspe River as modelled in the Goulburn System Model (G-MW and DSE's monthly REALM model of the Goulburn, Broken, Campaspe and Loddon systems), shortfalls were calculated at the delivery sites for the years where the maximum volume of water stored in Lake Eppalock from June to September was:

- < 150,000 ML
- 150,000 ML – 200,000 ML
- 200,000 ML – 250,000 ML
- > 250,000 ML.

These categories were used as surrogates for 'very dry', 'dry', 'median' and 'wet' years.

The median total shortfall in a wet year is 0 ML. However, total shortfalls of up to approximately 25,000 ML are possible in the wet years. For median and dry years, the median total shortfall ranges from 15,000 ML to 30,000 ML, depending on the Reach. Shortfalls are less in the very dry years than in the median and dry years, as there is no requirement to supply winter high flow events (Figure 4).

If the shortfalls are divided into components on the assumption that baseflows are met first before freshes are delivered, then it is clear that there is enough flow in Reach 2 to meet the baseflow recommendations in all except very dry years. For Reach 4, baseflow recommendations are generally met, but shortfalls increase moving from median to dry to very dry years. Reach 4 shortfalls in meeting baseflow recommendations are thought to be greater than for Reach 2 for two reasons:

- The baseflow recommendation is much larger for Reach 4 (200 ML/d compared with 120 ML/d).
- Passing flows provided under the existing bulk entitlements are lower for Reach 4 than for Reach 2.

The shortfalls in meeting freshes generally increase moving from wet to median to dry years. Freshes are not included in the environmental water demand in very dry years. Shortfalls in meeting freshes are greater in Reach 2 than in Reach 4, because four freshes of 1,000 ML/d lasting five days are required in Reach 2, whereas only two freshes of 1,500 ML/d lasting two days are required in Reach 4.

Note that the shortfall analysis presented in this document is based on modelled data. The scenario adopted for this analysis does not incorporate the changes associated with the decommissioning of the Campaspe Irrigation District as part of NVIRP. Decommissioning the Campaspe Irrigation District and the use of the entitlements and water savings by NVIRP will lead to changes in water supply in the Campaspe Basin. These changes may affect the shortfall in meeting environmental demands and hence the volumes required from environmental water reserves.

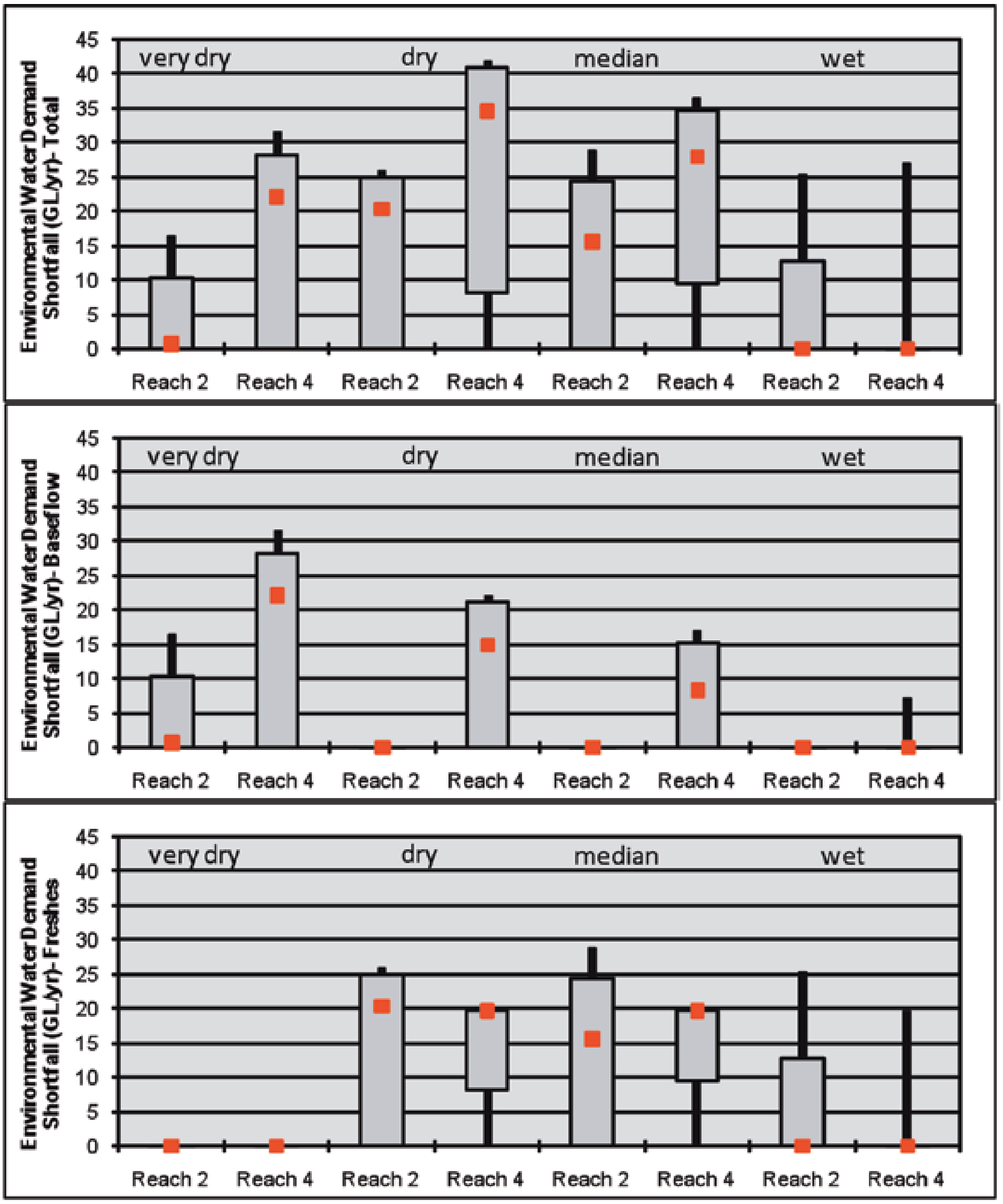

Figure 4: Shortfalls at the delivery site in meeting the winter environmental water demand in Reach 2 and Reach 4 of the Campaspe River (1895–2009). Median values are indicated by red boxes.

5. Operating regimes

5.1 Introduction

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

- Identifying the target environmental flow proposals for the coming season.
- Defining triggers to commence and cease delivering those proposed flows.
- Identifying any constraints on water delivery, such as available airspace in irrigation channels, 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 proposals

The selection of target environmental flows in each of the different climate years is triggered by the volume in Lake Eppalock, as shown in Table 9. The volume in storage has been used because it is linked to the release of minimum passing flows downstream of Lake Eppalock in G-MW's bulk entitlement (see Section 8 for further details). The same flow proposals are made for dry to wet years, so in practice a different set of proposals would only be implemented when the volume in storage is below 150,000 ML. If flow conditions change rapidly, such as in a major runoff event, consideration should be given to aiming for higher volume events associated with a wetter climate year. The selection of the suite of target flows should be flexible and in response to conditions in the Campaspe River because the flow thresholds for achieving the ecological benefits aligned with each threshold, particularly for the higher flow events, are not precisely known at the current time.

Table 9: Identifying seasonal target environmental flow proposals.

Climate year for selecting flow proposals	Volume in Lake Eppalock (ML)
Very dry	<150,000
Dry	150–200,000
Median	200–250,000
Wet	>250,000

5.3 Delivery triggers

Proposed operational triggers for delivering environmental flows are presented in Table 10.

The delivery of the baseflow requirements in all years occurs continuously over the season specified in the flow proposals and will occur from the nominated start date. These flows are within channel and can be delivered via releases from Lake Eppalock if not already being provided (for example, to meet inter-valley transfer requirements).

The freshes of 1,000–1,500 ML/d are required in all but very dry years. In many years, spills from Lake Eppalock will provide the desired events. In the absence of spills, it is suggested that recorded flows in Axe Creek at Goornong (gauge number 406214) be observed and releases ordered from Lake Eppalock to coincide with those runoff events. Achieving this in practice will be difficult, because runoff from catchments downstream of Lake Eppalock is often of short duration with only a short response time available. The volume to be released to achieve the desired peaks downstream will also be difficult to estimate without an operational rainfall-runoff model of Axe Creek. In the absence of a runoff event in Axe Creek to supplement flows, environmental water managers can order releases to be made from Lake Eppalock up to the release capacity of the reservoir. For the desired four events over six months, events are preferred on average every six weeks by the dates listed in Table 10.

In wet years, if the risk of a spill is high and there is still environmental water available at the start of June, consideration should be given to delivering a fresh event prior to 30 June, to avoid forfeit through transfer into the spillable water account.

It may not be possible to create the larger event in Reach 4 using only releases from Lake Eppalock. This is because flow peaks can be significantly attenuated when travelling between Lake Eppalock and Rochester. In these instances, it is recommended that the maximum volume is delivered from Lake Eppalock and then supplemented with water from the Waranga Western Main Channel to augment the peak flows as these pass the Campaspe Siphon.

The Commonwealth environmental water entitlements for the Campaspe system are available from Lake Eppalock for regulated river delivery along the Campaspe River downstream of the storage, while its entitlements for the Goulburn system are potentially available via the Waranga Western Main Channel (subject to available channel capacity). Additionally, Goulburn system entitlements are potentially available via the 150 ML/d Goldfields Superpipe between the Waranga Western Main Channel (at Colbinabbin) and Lake Eppalock (Coliban Water 2011), although this option would incur high pumping costs and use would need to be approved by Coliban Water, who use the pipe for urban supply.

Table 10: Summary of proposed operational regime to achieve environmental objectives.

Climate year	Flow objective in Campaspe River (Reach 2 and 4)	Season/ timing	Average return period	Trigger for delivery	Trigger for ceasing delivery
Very dry	Reach 2: 120 ML/d baseflow Reach 4: 200 ML/d baseflow	Jun–Nov	All very dry years	• Maintain throughout season with releases from Lake Eppalock as required. • Supplement with deliveries from Waranga Western Main Channel if insufficient allocation in Lake Eppalock and trade is hampered by lack of backtrade.	n/a
Dry to Wet	Reach 2: 120 ML/d baseflow Reach 4: 200 ML/d baseflow	Jun–Nov	All dry, median and wet years	• Maintain throughout season with releases from Lake Eppalock as required. • Supplement with deliveries from Waranga Western Main Channel if insufficient allocation in Lake Eppalock and trade is hampered by lack of backtrade.	n/a
	Reach 2: Four events of 1,000 ML/d for five days Reach 4: Two events of 1,500 ML/d for four days	Jun–Nov	All dry, median and wet years	Commence delivery from Lake Eppalock in response to anticipated runoff events in Axe Creek or by the following dates if an event has not occurred naturally: Event one of four: by 10 July* Event two of four: by 25 Aug Event three of four: by 10 Oct Event four of four: by 25 Nov Events two and four should be enhanced with releases from Lake Eppalock and/or the Waranga Western Main Channel if the Reach 4 event has not occurred naturally prior to these dates.	n/a

*In wet years if the risk of spill is high and allocations are still available, consider delivering this event prior to 30 June to avoid loss of carryover.

5.4 Storage releases

Historically, the outlet capacity of Lake Eppalock has been 1,850 ML/d when below full supply level (SKM 2006c); however the outlet capacity is limited to 1,000 ML/d when the Coliban Water turbines are offline. The capacity of the outlets works is sufficient to deliver the baseflow of 120–200 ML/d, as well as the 1,000 ML/d fresh events in Reach 2. Releases from storage alone are unlikely to be able to deliver the 1,500 ML/d fresh events in Reach 4, even when the Coliban Water turbines are operating. This is because of the significant attenuation of flood peaks along the Campaspe River. Delivering the 1,500 ML/d fresh event in Reach 4 would therefore be dependent on reservoir spills, tributary inflows or additional releases from the Waranga Western Main Channel at the upstream end of Reach 4.

5.5 Channel capacity

If the environmental water managers want to deliver water to the Campaspe River downstream of the Siphon from the Goulburn system, capacity constraints can occur seasonally in the Waranga Western Main Channel.

The channel does not operate from mid-May to mid-August when G-MW undertakes maintenance, although historically the channel has been operated every second winter to supply the Wimmera-Mallee channel system. After pipelining the Wimmera-Mallee channel system this is no longer required. If environmental water managers want to use the channel system during the non-irrigation season, they need to consult with G-MW well in advance of the end of the irrigation season to determine whether deliveries via the channel system could be maintained during the non-irrigation season. To use this option casual user charges would apply, along with operational water forfeit associated with running the channel from its own entitlement.

Approximate spare delivery capacities (ML/d) in the reach of the Waranga Western Main Channel upstream of the Campaspe Siphon are shown in Figure 5. This figure highlights, for example, that in a very dry year there is likely to be between 1,300–2,700 ML/d spare capacity in the channel. In a wet year it is possible that the channel will be operating at full capacity from November to April, but access is likely to be less limited than in the dry and median years, when capacity constraints are more prevalent. The availability of spare capacity in the channel decreases as the season progresses, so the ability of environmental water managers to use this infrastructure without delivery shares will diminish after September. If the Waranga Western Main Channel is to be used to deliver environmental water to the lower reaches of the Campaspe River, environmental water managers should check with G-MW regarding the likelihood of spare capacity at any given time.

The capacity of the outfall from the Waranga Western Main Chanel is documented as 1,470 ML/d, but is thought to be actually up to 2,300 ML/d under free fall conditions when there is no flow in the Campaspe River (SKM 2006c). This higher release rate would not be available to piggyback high river flow events. These release rates are sufficient to deliver the recommended pulse flows in Reach 4 of the Campaspe River.

Note that the assessment of channel capacity constraints is based on modelled channel use (i.e. modelled demand patterns). Future demand patterns may differ (for example, due to post-drought farm management practices) which may affect channel capacity constraints.

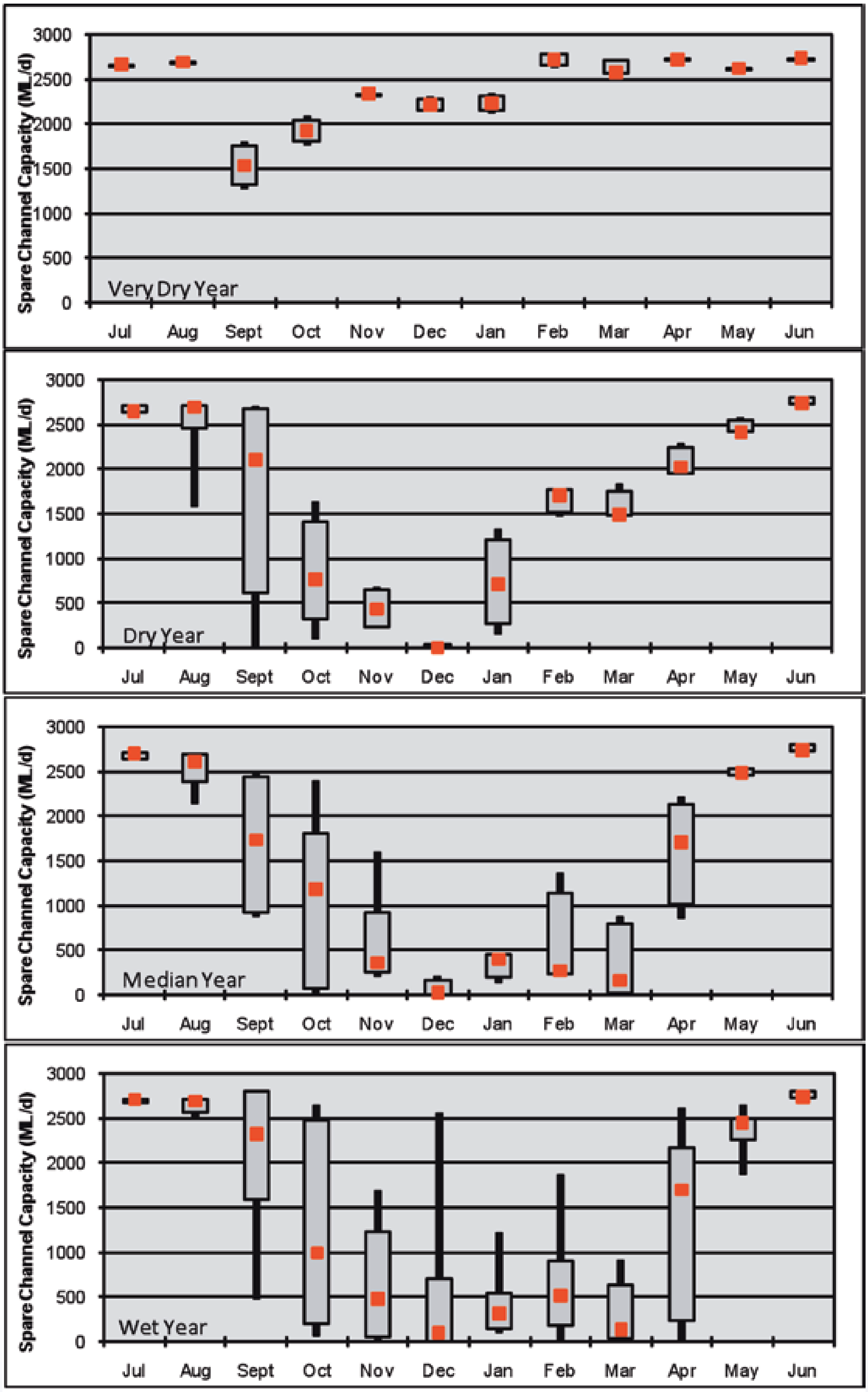

Figure 5: Spare channel capacity in the Waranga Western Main Channel upstream of the Campaspe Siphon, 1895–2009. Median values are indicated by red boxes.

5.6 Travel time

Figure 6 shows that it took five days in October 1997 for the peak of a 600 ML/d release from Lake Eppalock to reach the Campaspe River at Echuca (the confluence with the Murray River). The five-day travel time was comprised of one day between Lake Eppalock and Barnadown, two days between Barnadown and Rochester, and two days between Rochester and Echuca. The attenuation of the peak between Lake Eppalock and Echuca is also appreciable. This travel time was confirmed in other runoff events of magnitudes around 500–1,000 ML/d.

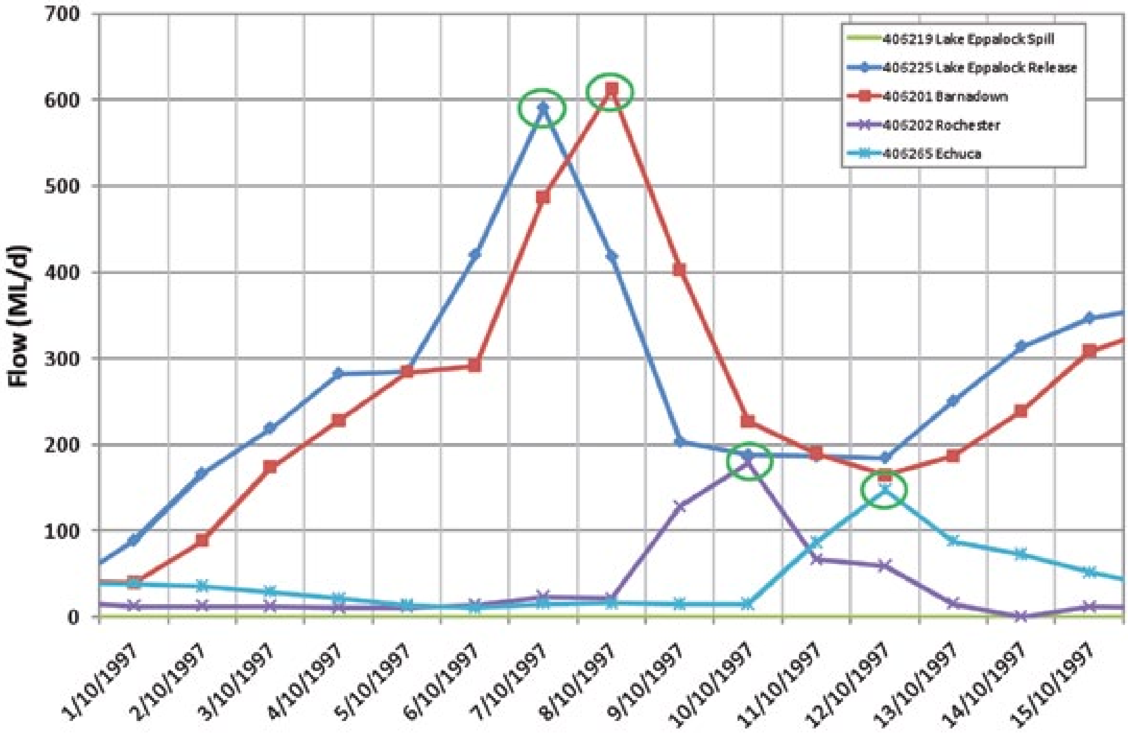

Figure 6: Travel time for a release from Lake Eppalock to reach the confluence of the Campaspe and Murray Rivers, October 1997.

As the release from Lake Eppalock reduces, the travel time increases. For example, in May 2003 it took 10 days for a release of approximately 125 ML/d to reach Echuca, including eight days between Barnadown and Echuca, as shown in Figure 7.

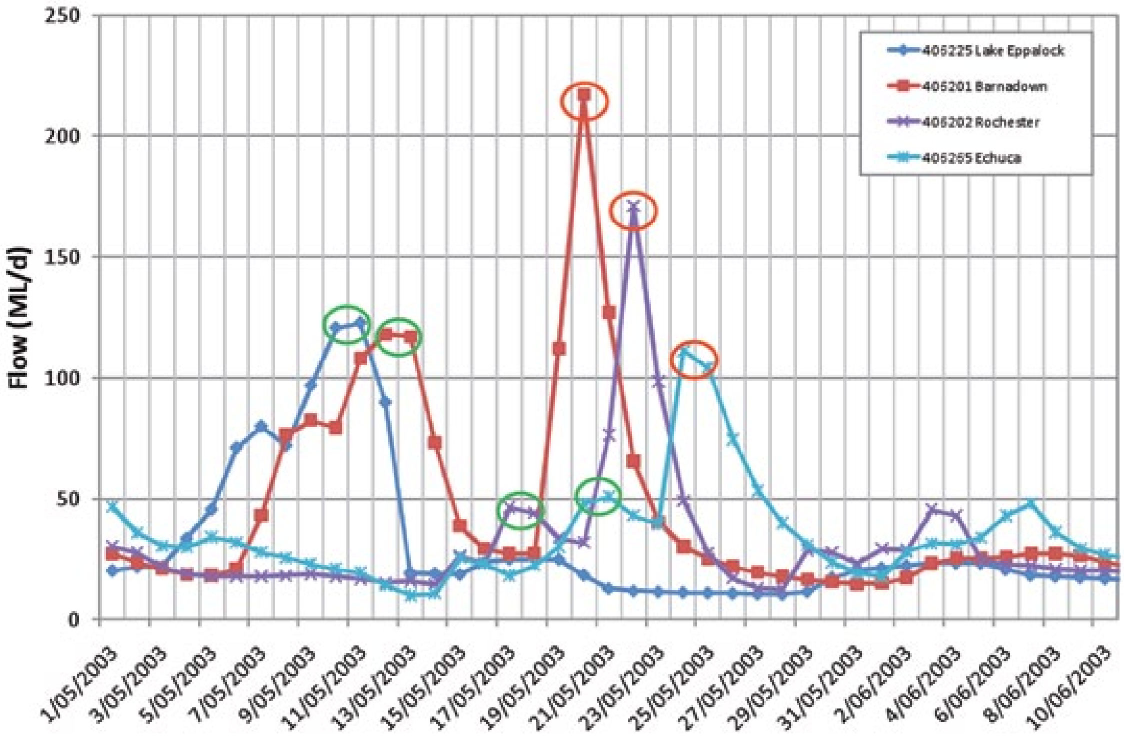

Figure 7: Travel time for a release from Lake Eppalock to reach the Murray River, May 2003.

Resources can be used more efficiently if releases are piggybacked onto natural flow events. Figure 8 shows the travel time for a peak observed on Axe Creek to reach Barnadown at a time when releases from Lake Eppalock were not driving flow. The travel time of approximately one day was the same as the travel time for releases from Lake Eppalock to Barnadown.

This means that if a peak is observed (or predicted) on Axe Creek, water can be released from Lake Eppalock and will reach Barnadown at approximately the same time, contributing to the peak magnitude of the event.

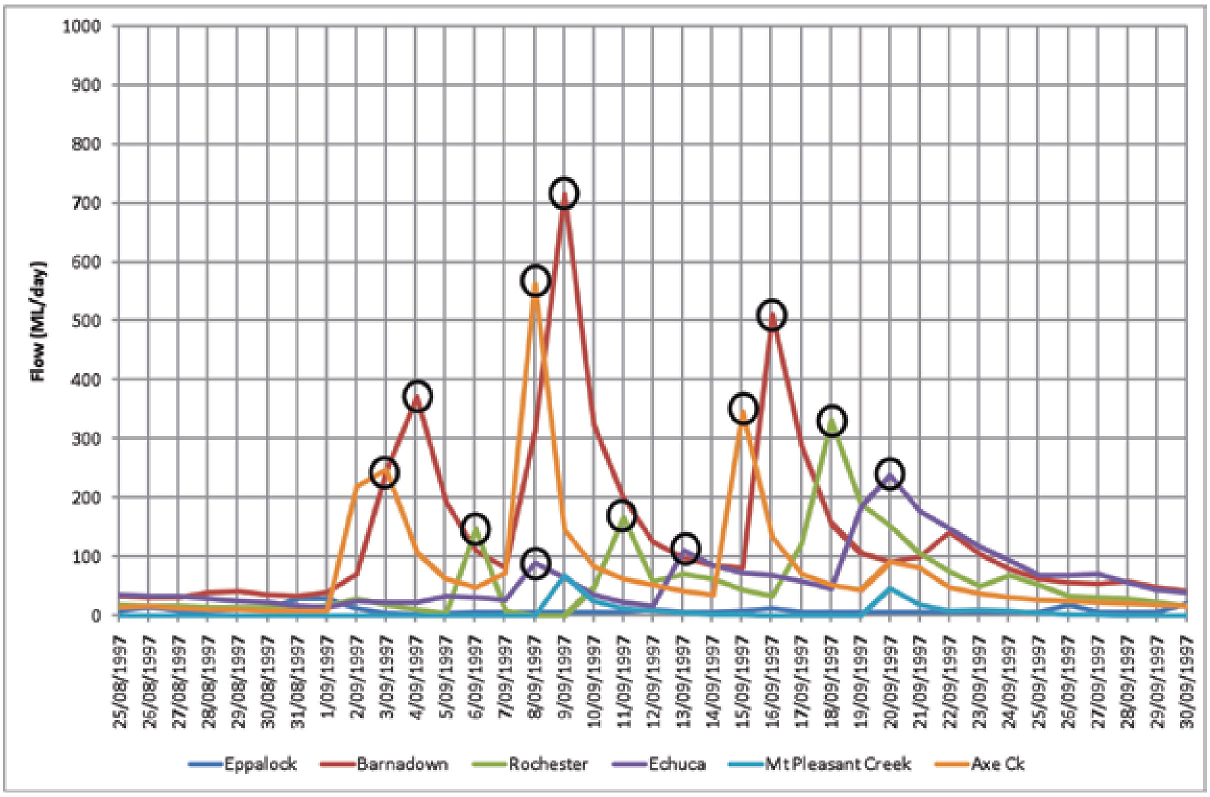

Figure 8: Travel time for a peak in Axe Creek to reach Barnadown and travel downstream.

Mt Pleasant Creek also contributes flows to the Campaspe River between Barnadown and Rochester. Mt Pleasant Creek is rarely the primary driver of flow in the Campaspe River and events on Mt Pleasant Creek are highly correlated to events on Axe Creek. This means that Mt Pleasant Creek is unlikely to be a suitable trigger of events (for piggybacking), but is likely to contribute to the magnitude of events downstream of the Mt Pleasant Creek confluence, reducing demand on environmental water resources.

Environmental water managers might also use the Waranga Western Main Channel to deliver environmental water allocations from the Goulburn system to supplement flow events in the Campaspe River at Rochester (downstream of the Siphon). G-MW requires an order four days in advance to guarantee delivery (although order times are expected to decrease with modernisation), and this is similar to or less than the time taken for flows from Lake Eppalock (or an event in Axe Creek) to reach Rochester if releases from Eppalock are more than a few hundred megalitres per day. This means that if a peak is observed on Axe Creek or releases are made from Lake Eppalock it may be possible to contribute to the peak magnitude of the event with deliveries from the Waranga Western Main Channel. This would require that orders are placed as soon as the event is observed or released.

Seasonal conditions also influence the nature of tributary responses (timing and magnitude) and need to be considered when attempting to piggyback natural flow events.

5.7 Flooding

Significant flooding has occurred historically in the vicinity of Rochester, including major floods in 2010–11. The minor flood level downstream of Lake Eppalock is 21,200 ML/d (Bureau of Meteorology 2011), which is well in excess of the peak flows recommended for delivery. The Rochester Caravan Park, which is adjacent to the Campaspe River, is evacuated at a flow of 19,000 ML/d at Rochester (SKM 2006b).

5.8 Water Delivery Costs

5.8.1 Delivery costs

There is no delivery cost for environmental water released from Lake Eppalock to the Campaspe River. However, if environmental water is delivered to the Campaspe River via the Waranga Western Main Channel, the delivery cost is likely to be in the order of $8 per ML for interruptible supply where spare channel capacity is available.

Note that delivery charges are subject to review on an annual basis. Refer to http://www.g-mwater.com.au/customer-services/feesandcharges for more information.

5.8.2 Carryover costs

Carryover is unlimited in the Campaspe system. However, carryover water is the first to spill after the environmental passing flow account. The 2011–12 fee for transferring water from the spillable water account back to an allocation bank account is $17.03 per ML for the Campaspe system. See http://www.g-mwater.com.au/customer-services/carryover#1 for more information.

5.9 Interactions with other assets

The Campaspe River is hydrologically connected to the Goulburn River via the Waranga Western Main Channel. Outflows from the Campaspe River contribute to streamflows in the Murray River downstream of Echuca and thus may contribute to flow events at downstream sites including Gunbower Forest and Koondrook-Pericoota Forest.

6. Governance and planning arrangements

6.1 Delivery partners, roles and responsibilities

The major strategic partners in delivering water to assets within the Campaspe system include:

- Victorian Environmental Water Holder (VEWH).
- North Central CMA as the environmental water manager for the Campaspe system.
- G-MW as the major BE holder, manager of Lake Eppalock, manager of the Campaspe Irrigation District and also the licensing authority responsible for groundwater and surface water licensed diversions.
- Coliban Water is responsible for urban water supply in the catchment and holds a bulk entitlement in Lake Eppalock and operates the Goldfields Superpipe from the Waranga Western Channel to Lake Eppalock.

Both the North Central CMA and G-MW cooperate with the GB CMA and the VEWH in the delivery of environmental water, particularly in relation to water transfers from the Goulburn to Campaspe systems.

6.2 Approvals, licenses, legal and administrative issues

6.2.1 Water shepherding and return flows

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 losses (if any) are taken into account.
- The return flows can be delivered in line with the timing requirements of the downstream user, purchaser or environmental site.
- The system operator can re-regulate the return flows downstream, with a known and immaterial spill risk, if the entitlement holder is requesting credits on a regulated system.

Commonwealth environmental water cannot currently be delivered from water shares in the Campaspe system, so allocations must be transferred to the VEWH for them to be used. If Commonwealth environmental water allocations are transferred to the Campaspe system environmental entitlement, held by the Victorian Environmental Water Holder in trust for The Living Murray, then the ability to reuse those flows in the Murray River depends on the conditions of that entitlement. Clause 15 of the entitlement allows the Victorian Minister for Water to grant water credits for return flows to the Murray River. However, Clause 6.2 of the entitlement states that the entitlement is to be used to meet Victoria's Living Murray obligations, which is facilitated by Clause 10.2. This specifies that the Victorian Minister for Environment "must assign all water allocated under the environmental entitlement each year to the holder of the *Bulk Entitlement (River Murray – Flora and Fauna) Conversion Order 1999*", which is held by the VEWH. This would mean that the conditions in the Campaspe system entitlement no longer apply and are governed by the conditions in the Flora and Fauna entitlement.

If Commonwealth environmental water allocations are temporarily transferred to the Flora and Fauna entitlement, then return flows to the Murray River can readily be credited under Clause 15 of that 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 the point of delivery from the Campaspe system is specified as Echuca (the confluence of the Campaspe River and the Murray River), this will ensure all of the regulated reaches of the Campaspe River will benefit from environmental releases from Lake Eppalock. However, if environmental water is delivered to Echuca from the Goulburn system via the Waranga Western Main Channel, only the Campaspe River downstream of The Siphon will benefit.

6.3 Trading rules and system accounting

6.3.1 Water trading

A map showing the Victorian and southern NSW water trading zones and summarising trading capability is shown in Figure 9. Table 11 summarises trading rules for southern NSW and Victorian trading zones.

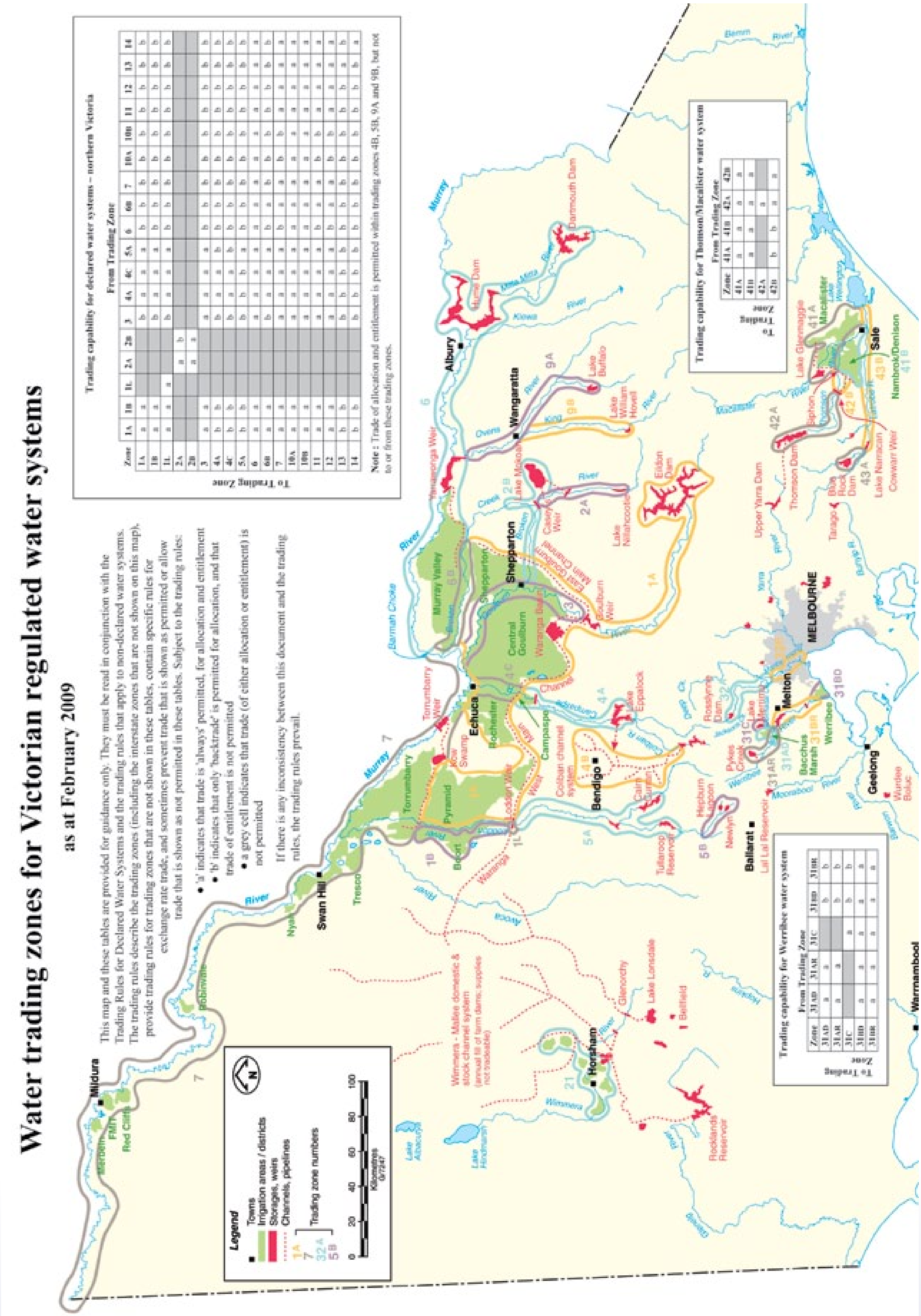

Figure 9: Victorian and southern NSW water trading zones and trading capability (DSE 2011).

Table 11: Victorian and southern NSW trading rules summary. Trading zones relevant to the Campaspe are highlighted.

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

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

The Campaspe River from Lake Eppalock to the Waranga Western Main Channel is located in Trading Zone 4A, while the Campaspe River from the Waranga Western Main Channel to the Murray River is located in Trading Zone 4C.

The volume of back trade at any given time is listed at: www.waterregister.vic.gov.au/Public/Reports/InterValley.aspx

Additional Trading Rules

All trade, except to unregulated tributaries, is with an exchange rate of 1.00. Trade into the unregulated river zones of the Campaspe (zone 140) can only be transferred as a winterfill licence, which becomes available in the following year. The water share volume is increased by 19 per cent when transferred to a winterfill licence, and decreased by 19 per cent when bought from a winterfill licence. Trade into Murray Irrigation Limited areas (zone 10B) attracts a 10 per cent loss of share volume.

Permanent trade is currently limited to four per cent per year from irrigation districts in Victoria. G-MW 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. For more information on water trading rules, see the Victorian Water Register (http://waterregister.vic.gov.au/).

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

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

This means that any allocation trades must be made well in advance of a targeted flow event.

Water trading attracts water trading fees. If water trading is conducted without the use of a broker, the fees are currently less than $80 for Victoria within State trade. See the Victorian Water Register for Victorian fee schedules at http://www.waterregister.vic.gov.au/Public/ApplicationFees.aspx.

6.3.2 Water storage accounting

Water storage accounting for the Campaspe is annual water accounting (July to June). Carryover is unlimited, but water above 100 per cent of the water share volume can be quarantined in a spillable water account when there is risk of Lake Eppalock spilling. Any carryover in the spillable water account cannot be accessed until the risk of spilling has passed (assessed by the G-MW Water Resources Manager based on storage levels and likely inflows). If a spill occurs, carryover in the spillable water accounts is the first to spill, but the volume forfeited is in proportion to the volume of spill (i.e. not all water in spillable water accounts is lost when the storage begins to spill).

The annual deduction for evaporation is five per cent of the volume carried over. The 2011–12 fee for transferring water from the spillable water account back to an allocation bank account is $17.03/ML for the Campaspe system. See http://www.g-mwater.com.au/customer-services/carryover#1 for more information.

7. Risk assessment and mitigation

The risk assessment outlined in Table 12 provides an indication of some of the risks associated with the delivery of environmental water in the Campaspe catchment. 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 full risk assessment must be undertaken prior to the commencement of water delivery. A framework for assessing risks has been developed by SEWPaC and is included at Appendix 4.

Table 12: Flow-related risks to environmental objectives for the Campaspe River.

Risk type	Description	Likelihood	Consequence	Risk level	Controls
Acid sulphate soils	No known risk.	Unlikely	Moderate	Low	N/A.
Salinity	Saline groundwater intrusion contributes to salinisation and stratification in pools in deeper sections of the lower Campaspe River. Saline water collects in the base of the pools and, under low flow conditions, less dense freshwater passes over the top without mixing. The stratification that results can have adverse effects on aquatic biota (SKM 2008, North Central CMA 2010). The extent to which exported salt may affect the Murray River requires further consideration.	Likely	Moderate	Medium	Flows should be managed to maintain the freshwater lens over the saline hypolimnium. Freshes will mix the pools but stratification recurs once baseflow is resumed. Aquatic biota is likely to be stressed if there are frequent fluctuations between stratified and non-stratified conditions.
Invasive species	Carp breeding is likely to be favoured by large flow events.	Likely	Moderate	Medium	N/A. Carp are very difficult to control.
Blackwater	Blackwater events have been recorded with the release of water after prolonged dry or low flow periods. Summer freshes will now only be released if there have been sufficient high flows in winter-spring to flush organic matter from the system.	Possible	Moderate	Medium	Ensure that antecedent conditions are such that they pose a low risk of blackwater events with the delivery of summer freshes.
Water loss	Water loss associated with inter-valley transfers was thought to be minimal (Cottingham et al. 2010). However, the recent drought has resulted in lowered watertables and there is anecdotal evidence that water losses were higher than originally thought. Losses under wetter conditions and at higher flows are still to be determined. (Geoff Earl, GB CMA, pers. comm.). It is possible that losses will again reduce following heavy recent rains and its effect on local groundwater levels (Darren White, North Central CMA, pers. comm.).	Possible	Minor	Low	Review losses for both dry and median conditions, and adjust allocations as required.
Other considerations	Given the reliance on using water delivered from the Goulburn system via the Waranga Western Main Channel to achieve the planned flows in Reach 4, the risk of not being able to access channel capacity at the times required may need assessment and consideration of control strategies.	Possible	Minor-moderate	Low-moderate	Review implications of limited channel capacity in Waranga Western Main Channel and develop control strategies.

8. Environmental water reserves

8.1 Environmental water holdings and provisions

8.1.1 Water planning responsibilities

The Northern Region Sustainable Water Strategy (NRSWS) provides the strategic direction for water management across northern Victoria (DSE 2009). It is also the document that identifies the community-agreed level of health for the Campaspe River, which the Victorian Government has agreed to try and meet by various means, including seeking water from environmental water managers. Planning and delivery of water specified by the Campaspe Bulk Entitlement is the responsibility of G-MW, which collaborates with DSE, the VEWH and the North Central CMA.

Environmental water shares on the Campaspe system can be delivered from Lake Eppalock. There is also the potential to deliver water shares from the Goulburn System to the lower Campaspe River (downstream of Campaspe Siphon) via the Waranga Western Main Channel. However, to transfer water in this way, environmental water managers are dependent on spare capacity being available in the Waranga Western Main Channel, if delivery shares are not held in the Goulburn system.

8.1.2 Environmental water provisions

Minimum passing flow requirements are specified in the amended Bulk Entitlement (G-MW Campaspe System) Conversion Order 2000 (Conversion Amending Notice 2005 and Conversion Amending Notice 2007). These are summarised in Table 13. The wording of the 2005 amendment to the Clause 11 passing flows in the context of the original clause is ambiguous and the passing flows below may differ slightly if an alternative interpretation of this amendment is adopted.

The 2005 amendment to the Bulk Entitlement established a passing flow account which allows additional passing flows to be released from G-MW's share of Lake Eppalock from 1 December to 30 June. These additional flows can only be released by agreement of all bulk entitlement holders with a share of Lake Eppalock and the storage operator. The volume in the passing flow account is calculated as the difference between the volume released to meet the current minimum passing flow requirements for the reach between the Campaspe Siphon and the Murray River (in Table 13) and the volume that would have been required to meet the minimum passing flow requirements in this reach in the original bulk entitlement, less any release to meet additional passing flows. Continuous accounting principles are applied to this account, with no limit set on the volume that may accumulate in the account. However, the volume in the account is reset to zero when Lake Eppalock spills.

Table 13: Minimum passing flow requirements for the Campaspe River.

Reach	Situation	Requirements
Reach 2 – between Lake Eppalock and Campaspe Weir	<150,000 ML in Lake Eppalock	• The lower of 10 ML/d or the actual inflow to Lake Eppalock, 1 July to 30 November.
	>150,000 ML but <200,000 ML in Lake Eppaloack	• The lower of 50 ML/d or the actual inflow to Lake Eppalock, 1 July to 30 November.
	>200,000 ML but <250,000 ML in Lake Eppalock	• The lower of 80 ML/d or the actual inflow to Lake Eppalock, 1 July to 30 November.
	>250,000 ML in Lake Eppalock	From 1 July to 30 November*: • The lower of 90 ML/d or the actual inflow to Lake Eppalock in January, March, May, June and December. • The lower of 80 ML/d or the actual inflow to Lake Eppalock in February and April. • The lower of 150 ML/d or the actual inflow to Lake Eppalock in July and November. • The lower of 200 ML/d or the actual inflow to Lake Eppalock in August, September and October.
Reach 4 – between Campaspe Siphon and Murray River	<200,000 ML in Lake Eppalock	• The lower of 20 ML/d or the 'modified natural flow' below the Campaspe Siphon from 1 July to 30 November. • The lower of 35 ML/d or the 'modified natural flow' below the Campaspe Siphon from 1 December to 30 June.
	>200,000 ML in Lake Eppalock	• 70 ML/d or the 'modified natural flow' below the Campaspe Siphon.

* It is noted that the interpretation of this clause is ambiguous (see above), for the purposes of this document it is assumed that only the requirements between 1 July and 30 November apply.

8.1.3 Current water holdings

Commonwealth environmental water holdings (as at October 2010) are summarised in Table 14. Campaspe water shares can be used in the Campaspe River directly while water shares from the Goulburn system can only be used if sufficient channel capacity to deliver the entitlements is available in the Waranga Western Main Channel, as the Australian Government does not hold delivery shares in the Goulburn system. Water shares from elsewhere in the connected southern Murray-Darling Basin can be traded into the Campaspe system, subject to the trading rules described in Section 6.3.

Environmental water currently held under Bulk Entitlements by the VEWH in the Campaspe system are summarised in Table 15.

Table 14: 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.

Table 15: Environmental water currently held under Bulk Entitlements by the VEWH.

Water holding	Volume	Comments
Environmental Entitlement (Campaspe River – Living Murray) Amendment Order 2009	5,048 ML low reliability water share and 126 ML high reliability water share for The Living Murray	Under this entitlement, allocations are transferred to the River Murray Flora and Fauna entitlement (held by the VEWH) prior to use.

8.2 Seasonal allocations

Campaspe and Goulburn system seasonal allocations in Schedule 3 of G-MW's Bulk Entitlements are a function of the volume stored in Lake Eppalock and Lake Eildon respectively. Figure 10 and Figure 11 provide a summary of October and April as indicative of spring and autumn seasonal allocations respectively for the Campaspe and Goulburn systems. This information is sourced from the MSM-Bigmod post-TLM run (#22061) and overestimates water availability in very dry years. Historically, zero allocations for high reliability water shares were recorded in the Campaspe system in 2006–07, 2008–09 and 2009–10 (G-MW 2011).

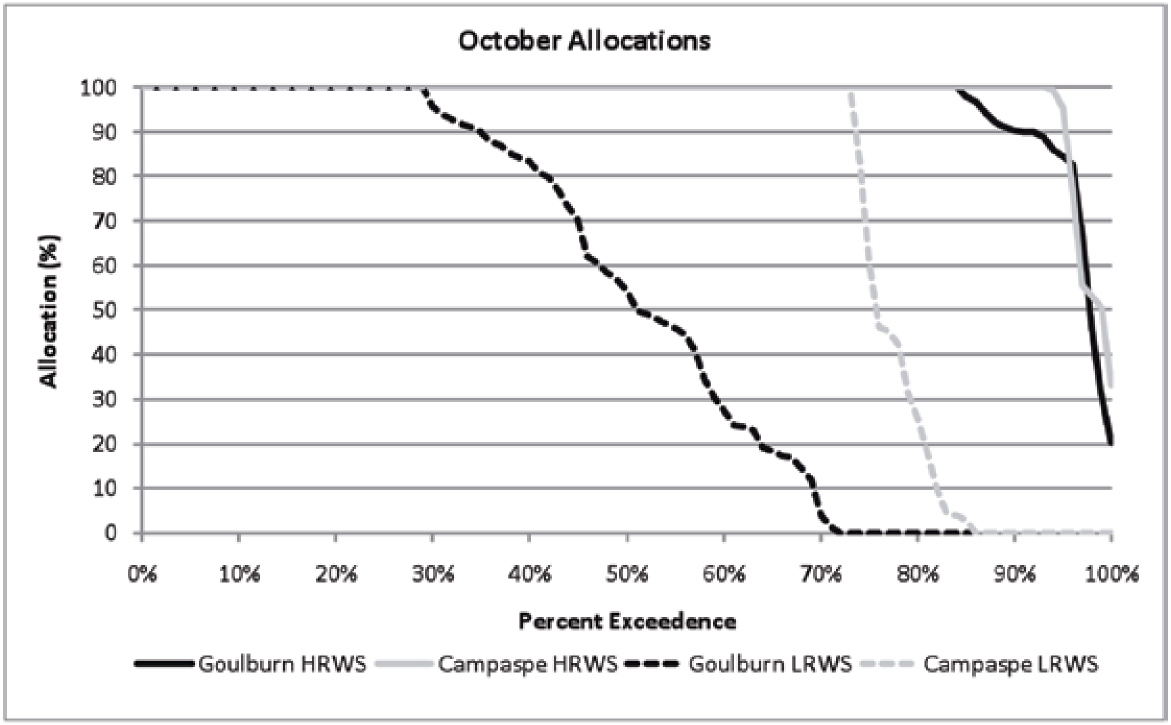

Figure 10: October seasonal allocations for the Campaspe and Goulburn systems.

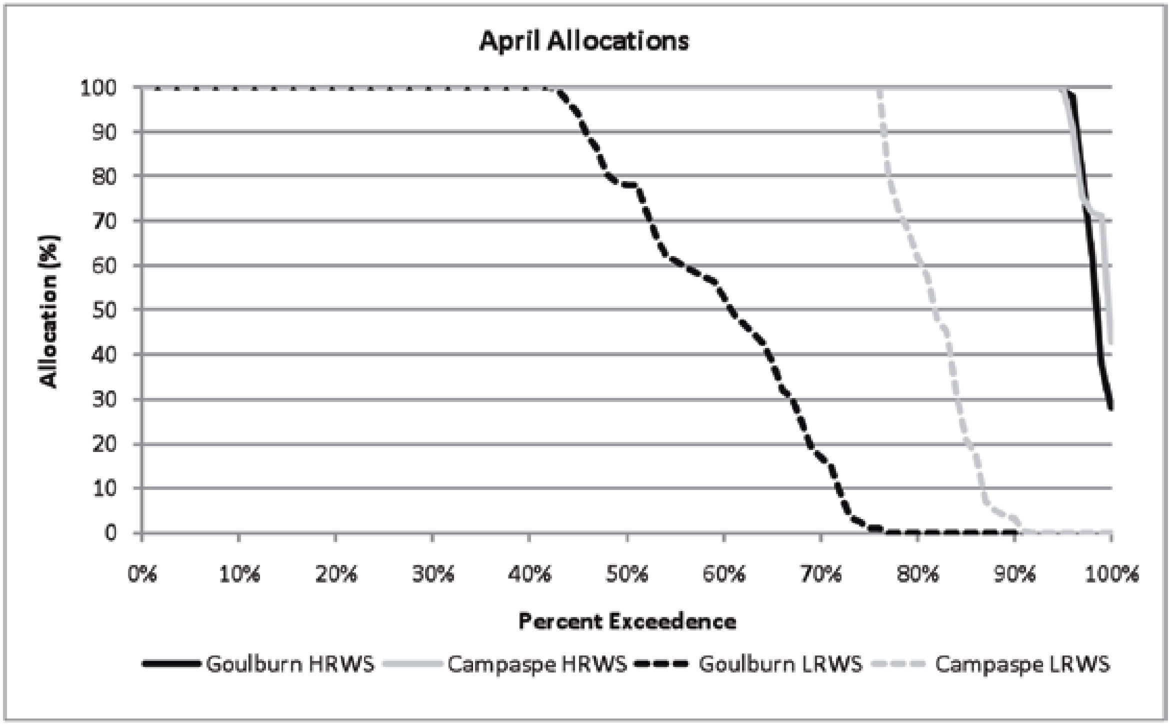

Figure 11: April seasonal allocations for the Campaspe and Goulburn systems.

Based on the MSM-Bigmod post-TLM run (#22061), the percentage allocation expected to be available to the environment under different climate conditions is summarised in Table 16. The volume of water expected to be available to the environment under different climate conditions is summarised in Table 17. This table shows, for example, that the availability of Commonwealth environmental water could be in the order of 33 percent of high reliability water shares (1,700 ML based on October 2010 holdings) in spring in a very dry year and 100 per cent allocations (5,500 ML based on October 2010 holdings) in a wet year.

If water is delivered from the Goulburn system to environmental flow Reach 4, then a further 20,000-75,000 ML could be available, depending on climate conditions (based on October 2010 holdings). If Commonwealth environmental water allocations were temporarily transferred from elsewhere in the southern connected Murray-Darling Basin to the Campaspe system, then up to 53,000 ML could be available in spring in a very dry year and up to 522,000 ML could be available in spring in a wet year (based on October 2010 holdings). However this volume of water is expected to only be available in Reach 4 (from the Goulburn system), as trade from the connected basins to Reach 2 (Campaspe system) is limited by available backtrade, which is minimal, as discussed in Section 6.3.

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). As stated previously, the models used to derive these allocations over-estimate allocation in very dry years.

Table 16: Likely allocation 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	100
Broken	High reliability water share	20.0	1	96	97	98	1	100	100	100
	Low reliability water share	4.2	0	0	0	0	0	100	100	100
Campaspe	High reliability water share	5,124.1	33	100	100	100	43	100	100	100
	Low reliability water share	395.4	0	100	100	100	0	100	100	100
Loddon	High reliability water share	1,179.0	0	100	100	100	0	100	100	100
	Low reliability water share	527.3	0	2	54	96	0	16	78	100
South Australia	High reliability	43,297.4	44	100	100	155	62	100	100	102

Table 17: Likely volume available to the environment from 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
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

Water availability forecasts for the Campaspe and Goulburn systems are provided by G-MW when allocation announcements are made. Allocation announcements are generally made on the 15th of each month (or the next business day), however when allocations to high reliability water shares are less than 100 per cent, 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, G-MW 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 G-MW's website (see Media Releases). Note that in years with high water availability, only the seasonal allocation outlook may be prepared.

PART 3:
Monitoring and Future Options

9. Monitoring, evaluation, and improvement

9.1 Introduction

Assessing ecosystem response to specific environmental flow releases as a form of intervention analysis is a challenging exercise (Chee et al. 2006). Being able to apply traditional study designs is usually problematic, as control sites (similar features to the test site, but without the intervention) are usually lacking and establishing 'before' conditions is difficult given the nature of river regulation and flows delivered from natural rainfall-runoff events. A number of monitoring and evaluation programs already exist that include the Campaspe River. However, nearly all of these programs were established for purposes such as water quality and river condition reporting, rather than specifically for assessing ecosystem effects resulting from changes to the flow regime. The Victorian Environmental Flows Monitoring and Assessment Program (VEFMAP) was however, established specifically to assess ecosystem response to new environmental flow regimes. VEFMAP is being implemented across northern Victorian rivers, including the Goulburn, Campaspe and Loddon Rivers (Chee et al. 2006, SKM 2007). Alignment of any future monitoring of environmental water use should occur in consultation with the VEWH and the North Central CMA.

An important consideration is that all parties to the allocation of environmental water should commit to a process of adaptive management. This means that the objectives, conceptual basis, implementation and evaluation of environmental releases should be clearly articulated and analysed in order to learn from experience. Evaluating the effectiveness of previously delivered flow events should also be the first action taken when planning for water management in subsequent years. While VEFMAP will provide long-term information on the effectiveness of environmental flow releases, it is based on longer-term objectives across numerous rivers assuming 'typical' climatic and hydrological conditions (Chee et al. 2006). Evaluating the effectiveness of environmental water may also require dedicated short-term investigation on mechanistic responses and evaluation of water management within and among individual assets (i.e. smaller scale hypotheses than for VEFMAP) to provide information on which to base future decisions.

The following sections provide a guide to the parameters that should be considered for future monitoring of environmental water releases. They do not provide guidance on aspects of study design, site selection and sampling frequency, as this is beyond the scope of this document.

9.2 Existing monitoring programs and frameworks

SKM 2007 provided an overview of current monitoring programs that include the Campaspe River. Existing information and monitoring includes:

- Cross-section surveys undertaken during environmental flow studies.
- Monthly water quality monitoring undertaken as part of the Victorian Water Quality Monitoring Network (VWQMN), as well as local continuous monitoring of dissolved oxygen, temperature and electrical conductivity.
- Fish surveys undertaken as part of the Murray Darling Basin Sustainable Rivers Audit (SRA) and local investigations.
- Macroinvertebrate sampling undertaken by EPA Victoria as part of its fixed sites network and as part of the SRA.

9.3 Operational water delivery monitoring

There are numerous long-term flow gauges along the Campaspe River. Key streamflow gauges along the river are listed in Table 18. A full list of available streamflow gauges can be found on the Victorian Water Resources Data Warehouse website (DSE 2010). G-MW collects operational flow data along the Waranga Western Main Channel and storage volume data for the headworks storages, which can be requested directly from G-MW.

The flow record for the Campaspe River at Echuca contains a number of missing periods which generally coincide with floods along the Murray River. During these times, water would have backed up the Campaspe River and drowned out the gauging station. Improved flow measurement devices will be installed in conjunction with planned construction of a fishway at the gauging station's weir.

Table 18: Flow monitoring in the Campaspe River catchment.

Site number	Site name	Relevance
406219	Campaspe River at Lake Eppalock (Head Gauge)	Spills from Lake Eppalock
406225	Campaspe River at Lake Eppalock (Outlet Meas. Weir)	Releases from Lake Eppalock
406207	Campaspe River at Eppalock	Flow downstream of Lake Eppalock
406201	Campaspe River at Barnadown	Flow in e-flow Reach 2
406218	Campaspe River at Campaspe Weir (Head Gauge)	Water level over Campaspe Weir (beginning of e-flow Reach 3)
406202	Campaspe River at Rochester	Flow at the beginning of Reach 4
406265	Campaspe River at Echuca	Flow at confluence with Murray River

In addition, the Department of Sustainability, Environment, Water, Population and Communities has developed a pro forma Environmental Watering Program Operational Monitoring Report (Appendix 2) to capture information related to releases, such as event details, risk management, initial observations and other issues.

9.4 Key parameters for monitoring and evaluating ecosystem response

The environmental watering objectives for the Campaspe River (see Section 2) relate to the delivery of flow components that support the following:

- Geomorphology – maintain current channel hydraulic geometry.
- Vegetation – rehabilitate riparian vegetation extent, structure and composition and increase diversity of instream vegetation.
- Water quality – reduce nutrient concentrations and salinity downstream of Axe Creek and reduce temperature impacts downstream of Lake Eppalock. Reduce salinity and improve dissolved oxygen throughout Reach 4.
- Fish – rehabilitate the native fish community through improved conditions for recruitment, maintenance and movement and link to Murray River fish communities.
- Macroinvertebrates – maintain current macroinvertebrate community diversity in edge habitats, increase diversity of riffle-dwelling species, increase diversity and abundance of pollution sensitive taxa and reduce the effect of temperature impacts downstream of Lake Eppalock.

A detailed program to monitor and evaluate ecosystem responses to environmental flows along the Campaspe River has been established as part of VEFMAP (Chee et al. 2006, also see Appendix 3). The monitoring and investigations established under VEFMAP provide a valuable starting point from which to assess ecosystem response to environmental flows, including those that may result from using environmental water. Further details on the VEFMAP recommended measures and sampling regime are provided in Chee et al. 2006.

In addition to the proposed VEFMAP monitoring measures, SKM 2007 recommended monitoring the following:

- Physical habitat surveys – river cross sections, qualitative estimate of habitat area and velocity, visual estimate of substratum composition, woody debris load assessment.
- Water quality assessment – monthly in-situ physico-chemical water-quality monitoring (e.g. DO, pH, EC, temperature, SS, nutrients); continuous dissolved oxygen, temperature and electrical conductivity.
- Riparian and in-channel vegetation surveys.
- Adult fish surveys.

SKM 2007 also recommended that directly monitoring macroinvertebrate populations was a low priority for the Campaspe River. While sampling of macroinvertebrate populations has not been included in the VEFMAP assessment of the Campaspe River, the habitat that supports macroinvertebrates is monitored as physical habitat (cross-section surveys) and estimates of habitat area, water velocity and substratum.

9.4.1 Potential monitoring gaps

VEFMAP was established to assess ecosystem responses to changes to watering regimes over time. It was not designed to assess ecosystem responses to individual or short-term flow events. The main issue for assessing the effectiveness of environmental water (in isolation) will be to establish a study design that provides the best possible inference that ecosystem response is due to any particular environmental release(s). Particular attention will be required on establishing the 'before' conditions to allow 'before-after' comparisons. Appropriate experimental designs are best considered once environmental water managers determine the type of flow release(s) (e.g. baseflow, fresh, overbank flow), and consideration is given to how the proposed experimental approach may complement monitoring being undertaken as part of VEFMAP. Monitoring considerations when planning to deliver environmental water are summarised in Table 19 (see also Appendix 3 for references to VEFMAP).

Table 19: Monitoring considerations for assessing the effectiveness of Commonwealth environmental water in Reaches 2–4 of the Campaspe River.

Asset / ecosystem attribute	Objective	Existing monitoring	Additional monitoring required	Considerations for this watering options project
Geomorphology	Maintain current channel hydraulic geometry.	Channel form is monitored at • Reach 2: two sites every five years; • Reach 3: one site every five years • Reach 4: two sites every five years.	Survey of distributaries.	Environmental water managers may consider contributing to a channel survey to provide new baseline conditions if this has not been done since the 2010 floods.
Water quality	Reach 2: reduce nutrient concentrations and salinity downstream of Axe Creek and reduce temperature impacts downstream of Lake Eppalock. Reach 4: reduce salinity and improve dissolved oxygen	Water quality is currently monitored at • Reach 2: four sites: monthly physico-chemical parameters (four sites) as well as continuous DO, EC and temperature (two sites). • Reach 3: four sites: monthly physico-chemical parameters (four sites) as well as continuous DO, EC and temperature (one site). • Reach 4: five sites: monthly physico-chemical parameters (four sites) as well as continuous DO, EC and temperature (three sites).	Event-based monitoring.	Water quality hypotheses require development to test response to the delivery of environmental water in isolation.
Riparian and in-channel vegetation	Rehabilitate riparian vegetation extent, structure and composition and increase diversity of instream vegetation.	Vegetation is monitored every three to five years at: • Reach 2: two sites. • Reach 3: one site. • Reach 4: two sites.	Frequency and timing of monitoring (before-after) to coincide with individual watering events should environmental water managers seek to measure the effect of their environmental water in isolation from the wider water regime.	VEFMAP can provide baseline information for assessing effects of environmental water on vegetation. However, additional or repeated measurements may be required to provide 'before' data in light of recent (2010) flood events.
Native fish	Rehabilitate native fish community through improved conditions for recruitment, maintenance and movement. Reach 4: rehabilitate native fish community through improved conditions for recruitment, maintenance, movement and links to Murray River fish communities.	Adult fish are monitored annually at: • Reach 2: six sites. • Reach 3: five sites. • Reach 4: five sites.		
Macro-invertebrates	Maintain current macroinvertebrate community diversity in edge habitats, increase diversity of riffle-dwelling species, increase diversity and abundance of pollution sensitive taxa and reduce effect of temperature impacts downstream of Lake Eppalock.	No macroinvertebrate monitoring is undertaken as part of VEFMAP. Habitat is monitored at two sites every five years or after events. EPA Victoria undertakes regular monitoring at several sites along the Campaspe River.		

10. Opportunities

10.1 Use of Goldfields Superpipe

Coliban Water recently constructed the 46.5 kilometre Goldfields Superpipe from the Waranga Western Main Channel at Colbinabbin to the Eppalock-Bendigo pipeline near Lake Eppalock. This 150 ML/d pipeline first operated in 2007 and is owned and operated as a joint venture between Coliban Water and Central Highlands Water. Its purpose is to provide a reliable urban water supply to Bendigo and on a further approximately 110 km through to Ballarat when traditional catchment storage volumes including Lake Eppalock are low.

The pipeline can also be operated to transfer water from the Goulburn system into the Lake Eppalock which is part of the Campaspe system (Coliban Water 2011). If environmental water managers are using spare capacity in the Waranga Western Main Channel to deliver environmental flows, they may be able to use this pipeline to deliver environmental flows to Reach 2 and 3 downstream of Lake Eppalock instead of only Reach 4 downstream of the Waranga Western Main Channel.

Availability and costs for use of the pipeline would need to be discussed with the Coliban Water / Central Highlands Water joint venture. The pipeline is less likely to be available in very dry years (Coliban Water, pers comm., Sept 2011).

10.2 Future use of Campaspe Weir

The Campaspe Irrigation District is being decommissioned as part of the Northern Victorian Irrigation Renewal Project (NVIRP). The future of infrastructure associated with delivery of water to the district is unknown at the current time. Further work is required on the potential opportunities to use water stored in Campaspe Weir to help deliver environmental flows to the lower Campaspe River, versus the benefits of maintaining or decommissioning the weir.

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Appendix 1: Flora and Fauna of the Campaspe River

The following tables detail the flora and fauna recorded from Reach 2,3 and 4 of the Campaspe River, and have been sourced from the EPBC Act, SEWPaC Protected Matters Search Tool website, the DSE biodiversity interactive map and North Central CMA (2009). Additional information on flora and fauna from across the North Central region (Campaspe and Loddon systems) can be obtained from the North Central Regional River Health Strategy (North Central CMA 2005).

Table 20: Lower Campaspe River species list.

Species name	Common name	EPBC status	Migratory species	Presence*	FFG listing **
Flora					
Amphibromus fluitans	River swamp wallaby-grass	V	-	May	-
Cullen parvum	Small scurf-pea	-	-	Known	L
Pimelea spinescens subsp. spinescens	Plains rice-flower	CE	-	Known	L
Sclerolaena napiformis	Turnip copperbur	E	-	Likely	L
Swainsona murrayana	Slender darling-pea	V	-	Likely	L
Swainsona plagiotropis	Red darling-pea, red Swainson-pea	V	-	Known	L
Swainsona sericea	Silky Swainson-pea	-	-	Known	L
Invertebrates					
Synemon plana	Golden sun moth	CE		May	L
Fish					
Craterocephalus fluviatilis	Murray hardyhead	V		Likely	L
Maccullochella peelii peelii	Murray cod	V		Known	L
Macquaria australasica	Macquarie perch	E		Known	L
Amphibians					
Litoria raniformis	Growling grass frog	V		Likely	L
Reptiles					
Aprasia parapulchella	Pink-tailed worm-lizard	V		Likely	L
Delma impar	Striped legless lizard	V		Likely	L

Species name	Common name	EPBC status	Migratory species	Presence*	FFG listing **
Birds					
Apus pacificus	Fork-tailed swift	-	Marine	May	-
Ardea alba	Great egret, white egret	-	Marine / wetland	May	-
Ardea ibis	Cattle egret	-	Marine / wetland / terrestrial	May	-
Ardea modesta	Eastern great egret	-	Marine	Known	-
Burhinus grallarius	Bush stone-curlew	-		Known	L
Chthonicola sagittata	Speckled warbler	-		Known	L
Gallinago hardwickii	Latham's snipe, Japanese snipe	-	Wetland	May	-
Haliaeetus leucogaster	White-bellied sea-eagle	-	Terrestrial	Likely	L
Hirundapus caudacutus	White-throated needletail	-	Terrestrial	May	-
Lathamus discolor	Swift Parrot	E		Known	L
Melanodryas cucullata cucullata	Hooded robin	-		Known	L
Merops ornatus	Rainbow bee-eater	-	Terrestrial	May	-
Myiagra cyanoleuca	Satin flycatcher	-	Terrestrial	Likely	-
Ninox connivens connivens	Barking owl	-		Known	L
Pedionomus torquatus	Plains-wanderer	V		Likely	L
Polytelis swainsonii	Superb parrot	V		May	L
Pomatostomus temporalis temporalis	Grey-crowned babbler	-		Known	L
Porzana pusilla palustris	Baillon's crake	-		Known	L
Rostratula australis	Australian painted snipe	V		May	L
Rostratula benghalensis s. lat.	Painted snipe	-	Wetland	May	-
Stagonopleura guttata	Diamond firetail	-		Known	L
Xanthomyza Phrygia	Regent honeyeater	-	Terrestrial	May	L

Species name	Common name	EPBC status	Migratory species	Presence*	FFG listing **
Mammals					
Dasyurus maculatus maculatus (SE mainland population)	Spot-tailed quoll	E		Known	L
Nyctophilus timoriensis (South-eastern form)	Greater long-eared bat	V		May	L
Petaurus norfolcensis	Squirrel glider	-		Known	L
Phascogale tapoatafa tapoatafa	Brush-tailed phascogale	-		Known	L

E Endangered

CE Critically endangered

L Listed (threatened)

V Vulnerable

The presence of species has been ascertained through:

* EPBC Act, Protected Matters Search Tool website
Department of Sustainability and Environment, Biodiversity Interactive Map website
Victorian Department of Sustainability and Environment (2007) Advisory List of Threatened Vertebrate Fauna in Victoria – 2007. Department of Sustainability and Environment, East Melbourne, Victoria.

** Department of Sustainability and Environment (2005) Advisory List of Rare or Threatened Plants in Victoria – 2005. Victorian Department of Sustainability and Environment, East Melbourne, Victoria.
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Appendix 2: Operational Monitoring Report

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 two 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).

Appendix 3: Summary of VEFMAP monitoring

Table 21: Summary of VEFMAP monitoring arrangements for environmental water use in the Campaspe River (from SKM 2007, Chee et al. 2006).

Flow component	Hypotheses	Indicator(s)	Monitoring sites	Frequency	Considerations for this watering options project
Geomorphology					
Winter/spring freshes	Does increased frequency of winter-spring fresh events: a) increase the frequency of geomorphologically significant events (e.g. redistribution of bed and bank sediments)? b) increase channel complexity (e.g. areas of the stream bed which are flushed free of fine deposits, deeper pools and variability in bench elevations)? c) increase channel width and depth? d) increase rates of meander development (i.e. bank erosion on the outside bank, point bar development, increased sinuosity and eventually bend cut-off and billabong formation)?	Flow and physical habitat (channel dimensions) to assess: • Frequency of channel disturbances • Frequency of bed disturbances • Rate of bench deposition • Bed complexity • Bench development and variability • Mean channel top width, cross-section area and thalweg depth • Bank erosion on outside of meander bends • Point bar development.	Reach 2: 2 sites Reach 3: 1 site Reach 4: 2 sites	Every 5 years, event based.	VEFMAP provide baseline information for assessing effects of environmental water. May require repeat measurements to provide 'before' data if channel dimensions have not been surveyed after recent (2010) flood events.
Bankfull	As above	As above	As above	As above	As above

Flow component	Hypotheses	Indicator(s)	Monitoring sites	Frequency	Considerations for this watering options project
Habitat and macroinvertebrates					
Summer/autumn low flows and freshes	• Do implemented environmental flows maintain in-channel shallow and slow water area? • Do implemented environmental flows maintain adequate area and depth of at least 0.1 m in shallow, slow water and riffle/run habitats? • Do implemented environmental flows maintain adequate volume and depth in permanent pools? • Do implemented environmental flows maintain connectivity? • Do implemented environmental flows maintain macroinvertebrate community structure? • Do implemented environmental flows increase fish recruitment? • Do implemented environmental flows maintain fish assemblages and/or population structure?	• Shallow and slow water area • Riffle/run depth and area • Permanent pool depth and volume • Connectivity • Number of invertebrate families index • AUSRIVAS score • SIGNAL biotic index • EPT biotic index • Presence/absence and number of 'flow-sensitive' taxa • See conceptual model for fish spawning & recruitment • Fish species composition • Relative abundance of adult/ sub-adult native and exotic fish species • Population structure and size class distribution of native and exotic fish species.	*Macroinvertebrates in the Campaspe are not monitored as part of VEFMAP.* Physical habitat monitored at: Reach 2: 2 sites Reach 3: 1 sites Reach 4: 2 sites	Every 5 years, event based.	As above VEFMAP sampling was not designed to assess short-term changes. Will require more frequent 'before' and 'after' sampling if the effects of environmental water are to be assessed in isolation.

Flow component	Hypotheses	Indicator(s)	Monitoring sites	Frequency	Considerations for this watering options project
Winter/spring baseflows	• Do implemented environmental flows increase in-channel shallow and slow water area? • Do implemented environmental flows increase area of riffle and/or run habitat? • Do implemented environmental flows increase volume of permanent pool habitats? • Do implemented environmental flows result in sustained inundation of in-channel macrophytes, channel edge macrophytes, tree roots, woody debris, branch piles, in-channel bars, overhanging or undercut banks? • Do implemented environmental flows increase abundance of macrophytes? • Do implemented environmental flows improve macroinvertebrate community structure? • Do implemented environmental flows improve fish assemblages and/or population structure?	• Shallow and slow water area • Riffle and/or Run area • Permanent pool depth and volume • Inundation of representative physical habitat features • See conceptual model for Aquatic and Riparian Vegetation • Cover of submerged and amphibious species • Cover of submerged and amphibious species • Number of invertebrate families index • AUSRIVAS score • SIGNAL biotic index • EPT biotic index • Presence/Absence and number of 'flow-sensitive' taxa • Fish species composition • Relative abundance of adult/sub-adult native and exotic fish species • Population structure and size class distribution of native and exotic fish species.	As above	As above	As above VEFMAP sampling was not designed to assess short-term changes. Will require more frequent 'before' and 'after' sampling if the effects of environmental water are to be assessed in isolation.

Flow component	Hypotheses	Indicator(s)	Monitoring sites	Frequency	Considerations for this watering options project
Winter/spring freshes	• Do implemented environmental flows increase area of riffle and/or run habitat? • Do implemented environmental flows increase volume of pool habitats • Do implemented environmental flows result in temporary inundation of higher-level channel edge macrophytes, tree roots, woody debris, bars, benches, overhanging/undercut banks? • Do implemented environmental flows improve macroinvertebrate community structure? • Do implemented environmental flows improve fish assemblages and/or population structure?	• Riffle and/or run area • Permanent pool depth and volume • Inundation of higher elevation representative physical habitat features • Number of invertebrate families index • AUSRIVAS score • SIGNAL biotic index • EPT biotic index • Presence/absence and number of 'flow-sensitive' taxa • Fish species composition • Relative abundance of adult/sub-adult native and exotic fish species • Population structure and size class distribution of native and exotic fish species.	As above	As above	As above

Flow component	Hypotheses	Indicator(s)	Monitoring sites	Frequency	Considerations for this watering options project
Aquatic and riparian vegetation					
Spring baseflow	• Do implemented environmental flows increase in-channel shallow and slow water area? • Do implemented environmental flows increase run area? • Do implemented environmental flows result in sustained inundation of channel bed, channel edges, in-channel bars, low-lying benches, runners and anabranches in Zone A*? • Do implemented environmental flows a) increase germination and seasonal growth of submerged and amphibious fluctuation-responder species in Zone A*? b) reduce species richness of terrestrial 'dry' species in Zone A*?	• Shallow and slow water area • Run depth and area • Inundation of geomorphic features in Zone A* • Cover of submerged and amphibious species in Zone A* • Species composition, number of submerged, amphibious and terrestrial species in Zone A* • Proportion of exotic plant species.	Reach 2: 2 sites Reach 3: 1 sites Reach 4: 2 sites	Every 3–5 years, late spring	As above
	• What is the pattern of inundation and drying in Zones A* & B* imposed by the implemented environmental flows? • What is the composition of the resultant plant community?	• Cover of amphibious and terrestrial species in Zones A* & B* • Species composition, number of amphibious and terrestrial species in Zones A* & B* • Proportion of exotic plant species	As above	As above	As above

Flow component	Hypotheses	Indicator(s)	Monitoring sites	Frequency	Considerations for this watering options project
Spring freshes & bankfull flows	• Do implemented environmental flows wet high-level benches, upper banks, runners and anabranches in Zones B* & C*? • Do implemented environmental flows increase germination and establishment of terrestrial 'damp', terrestrial 'dry' and amphibious fluctuation-tolerator species? • Do implemented environmental flows improve canopy condition of in situ riparian trees and shrubs?	• Wetting of geomorphic features in Zones B* & C* • Species composition, number of amphibious and terrestrial species in Zones B* & C* • Proportion of exotic plant species • Germination of seedlings of over-storey and mid-storey species • Canopy condition.	As above	As above	As above
Summer baseflow	• Do implemented environmental flows maintain area of in-channel shallow and slow water and run habitats? • Do implemented environmental flows wet in-channel bars, low-lying benches, channel edges, runners and anabranches in Zone A*? • Do implemented environmental flows improve canopy condition of adjacent riparian trees and shrubs?	• See conceptual model for Habitat Processes • Shallow and slow water area • Run depth and area • Wetting of geomorphic features in Zone A* • Canopy condition.	As above	As above	As above
Native fish					
Autumn-early winter freshes/bankfull flows	• Do implemented environmental flows trigger spawning of diadromous fish? (Only relevant in river reaches inhabited by diadromous fish species such as galaxiids, eels and Australian Grayling)	• Presence/absence of diadromous fish larvae	Reach 2: 6 sites Reach 3: 5 sites Reach 4: 5 sites	Annually, November–April	VEFMAP may be appropriate for considering effects of environmental water, but it may also be difficult to separate from other influences, including recent flow history (i.e. antecedent conditions).

Flow component	Hypotheses	Indicator(s)	Monitoring sites	Frequency	Considerations for this watering options project

Winter–spring baseflows and winter–spring freshes	• Do implemented environmental flows increase overall quantity and diversity of instream habitat?	• See conceptual model for Habitat Processes
		  • Shallow and slow water area
		  • Run area
		  • Permanent pool depth and volume
		  • Inundation of physical habitat features
		  • Inundation of higher elevation physical habitat features
		  • In-channel and littoral cover of macrophytes.
			As above	Annually, November–April	As above

Spring–early summer bankfull flows	• Do implemented environmental flows inundate low-lying runners and anabranches to create increased slackwater habitat? • Do implemented environmental flows increase the number of fish completing larval stages?	• Area of slackwater habitat in runners and anabranches • Density of post-larval fish.	As above	Annually, November–April	As above

Spring–early summer baseflows	• Do implemented environmental flows provide appropriate conditions for spawning and larval production of 'low flow specialist' and generalist fish species?
	• Do implemented environmental flows maintain adequate instream habitat for adult and larval fish?
	• Do implemented environmental flows increase the number of fish completing larval stages?
		Presence/Absence of 'low flow specialist' and generalist fish larvae
		• See conceptual model for Habitat Processes
		  • Shallow and slow water area
		  • Run area
		  • Permanent pool depth and volume
		  • Connectivity
		• Density of post-larval fish
			As above	Annually, November–April	As above

Flow component	Hypotheses	Indicator(s)	Monitoring sites	Frequency	Considerations for this watering options project
Spring–early summer overbank flows	• Do implemented environmental flows inundate low-lying runners and anabranches to create increased slackwater habitat? • Do implemented environmental flows inundate floodplain areas to create increased slackwater habitat? • Do implemented environmental flows provide appropriate conditions for spawning and larval production of 'flood specialist' non-diadromous fish species? • Do implemented environmental flows increase the number of fish completing larval stages?	• Area of slackwater habitat in runners and anabranches • Area of slackwater habitat in floodplain • Presence/Absence of 'flood specialist' non-diadromous fish larvae • Density of post-larval fish.	As above	Annually, November–April	As above

Summer–autumn low flows	• Do implemented environmental flows maintain adequate instream habitat for adult and larval fish?
	• Do implemented environmental flows increase the number of fish completing larval stages?
		• See conceptual model for Habitat Processes
		  • Shallow and slow water area
		  • Run area
		  • Permanent pool depth and volume
		  • Connectivity
		• Density of post-larval fish
			As above	Annually, November–April	As above

Water Quality					
All components (year- round)	• No specific hypotheses	Colour, dissolved organic carbon, dissolved reactive phosphorus, electrical conductivity, total Kjeldahl nitrogen, oxidized nitrogen, pH, total phosphorus and turbidity.	Reach 2: 4 sites Reach 3: 4 sites Reach 4: 5 sites	Continuous DO, EC and temperature. Monthly physico-chemical measurements.	Dedicated monitoring program may be required, depending on the water quality variable to be tested.

*See Chee et al. (2006) for details

Appendix 4: Risk assessment framework

Risk likelihood rating

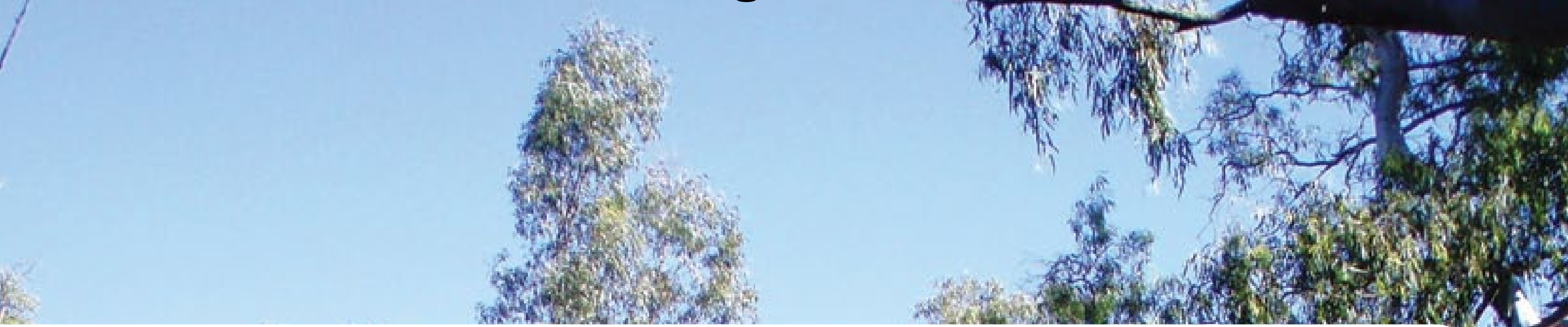
Almost certain	Is expected to occur in most circumstances
Likely	Will probably occur in most circumstances
Possible	Could occur at some time
Unlikely	Not expected to occur
Rare	May occur in exceptional circumstances only

Risk consequence rating

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

Risk analysis matrix

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



Australian Government

Commonwealth Environmental Water

ENVIRONMENTAL WATER DELIVERY:

Edward Wakool System

MAY 2011 V1.1

Image Credits

Wakool River at Calimo Road
©DSEWPaC; Photographer Rebecca Gee

Juvenile straw-necked ibis, Wanganella Swamp
©DSEWPaC; Photographer Simon Banks

V1.1 Updated in September 2011 to include a correction.

Hale, J and SKM (2011). Environmental Water Delivery: Edward-Wakool. Prepared for Commonwealth Environmental Water, Department of Sustainability, Environment, Water, Population and Communities.

ISBN: 978-1-921733-21-5

SEWPaC acknowledges the following individuals and organizations that have been consulted in the preparation of this document:

NSW Office of Water
Murray Catchment Management Authority
NSW State Water
Garry Smith (DG Consulting)
Ben Gawne (Murray-Darling Freshwater Research Centre)
Daren Barma (Barma Water Resources)

Published by the Commonwealth Environmental Water Holder for the Australian Government.

ENVIRONMENTAL WATER DELIVERY:
Edward Wakool System

MAY 2011 V1.1

Environmental Water Delivery: Edward-Wakool

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; and
- 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 Edward-Wakool system.

The Edward-Wakool system supports important ecological values including twenty significant flora and fauna species. Potential water use options for the Edward-Wakool system include: providing base flows to Jimaringle and Cockrans Creeks to maintain in stream water quality; augmenting natural flows to improve connectivity between the river channel and floodplains within Werai Forest; and providing pulse flows in the Edward-Wakool rivers to promote ecosystem function for in-channel flora and fauna.

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

The work has been undertaken by consultants on behalf of the Commonwealth Department of Sustainability, Environment, Water, Population and Communities. Previously prepared work has been drawn upon and discussions have occurred with organisations such as the NSW Office of Environment and Heritage, NSW Office of Water, 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: cewh@environment.gov.au . Further information about Commonwealth environmental water can be found at www.environment.gov.au\ewater.

Commonwealth Environmental Water
Department of Sustainability, Environment, Water, Population and Communities
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Acronyms

ACRONYM	MEANING
AEW	Adaptive environmental water
CEWH	Commonwealth Environmental Water Holder
COAG	Council of Australian Governments
CSU	Charles Sturt University
DO	Dissolved oxygen
DSE	Victorian Department of Sustainability and Environment
DWE	NSW Department of Water and Environment
EWRs	Environmental Water Holders
G-MW	Goulburn-Murray Water
IVTs	Inter-valley transfers
Murray CMA	Murray Catchment Management Authority
MDBA	Murray-Darling Basin Authority
MIL	Murray Irrigation Limited
MLD EWAG	Murray Lower Darling Environmental Water Advisory Group
MWWG	Murray Wetlands Working Group
NPWS	NSW National Parks and Wildlife Service
OEH	NSW Office of Environment and Heritage
NOW	NSW Office of Water
SEWPAC	Department of Sustainability, Environment, Water, Population and Communities
TLM	The Living Murray

PART 1:
Management Aims

1. Overview

1.1 Scope and purpose of this document

Information provided 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 water use options for large volumes of environmental water.

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

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

As part of this project, assets and potential watering options have been 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 options have been developed for each asset to meet watering objectives under a range of volume 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 that are required to operationalise environmental water use strategies are documented and include such things as:
   - delivery arrangements and operating procedures;
   - water delivery accounting methods that are either currently in operation at each asset 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; and
   - approvals and legal mechanisms for delivery and indicative costs for implementation.

This document focuses on the delivery of water to the Edward-Wakool system to achieve positive environmental outcomes. It should be noted, however, that the Edward-Wakool system is within the larger water planning area of the Central Murray Floodplains (Yarrawonga to the Wakool junction). The actions and activities identified within this document must be considered in conjunction with adjoining environmental delivery documents for the Barmah-Millewa, Koondrook-Perricoota and Gunbower Forests.

1.2 Catchment and river system overview

The Edward–Wakool River System is a major anabranch and floodplain of the River Murray, located in southern NSW. It consists of a network of inter-connecting rivers, creeks, floodrunners and wetlands and covers more than 1,000 square kilometres between the Murray and Edward Rivers (Figure 1). The hydrology of the Edward-Wakool system is complex, as flows into the wider Murray system can originate from a variety of sources. These include the upper Murray, Billabong and Murrumbidgee catchments in NSW, and Victorian tributaries such as the Kiewa, Ovens, Goulburn, Campaspe, Loddon and Avoca Rivers.

The main water sources into the Edward-Wakool Rivers under regulated flow conditions are from the River Murray via the Edward River and Gulpa Creek, which originate in the Barmah-Millewa Forest and from the Edward Escape, an outlet of Mulwala Canal. However, during high flows the system is supplemented with water from the River Murray via a number of other creeks. These include creeks running through the Millewa Forest such as Toupna Creek, the Bullatale and Tuppal Creeks that enter the Edward River upstream of Deniliquin, and the Thule, Barbers, Little Merran and Waddy Creeks, which flow out of the River Murray between Echuca and Swan Hill and flow into the lower Wakool River. There are also inflows to the Edward-Wakool system from the north-east via Billabong Creek, which flows into the Edward River at Moulamein (Green 2001). The intermittent stream network also connects to a number of large depressional wetlands such as Poon Boon Lakes, Coobool Swamp and Lake Agnes.

The extent of the system can be defined as from the junction of Wee Wee Creek and the River Murray to the junction of Tuppal Creek and Edward River. The system comprises the anabranch floodplain of the Edward-Wakool Rivers including the Edward River downstream of Deniliquin, the Niemur River, Colligen Creek (and associated watercourses; the Cockran and Jimaringle Creeks), the Wakool River and Yallakool Creek between Stevens Weir and the confluence with the Murray. It also covers a series of effluents that link the River Murray to the Wakool River (Little Merran, Merran, St Helena, Mulligan's, Larry's, Coobool and Waddy Creeks).

The Edward-Wakool system spans three local government areas (Conargo Shire Council, Murray Shire Council and Wakool Shire Council). Land tenure is predominantly freehold, although there are a number of former State Forests, the majority of which were declared national parks on 1 July 2010. The largest of these is Werai Forest (approximately 11, 400 hectares) on the Edward River (fed from Colligen Creek), which is a proposed Indigenous Protected Area. Land use is predominantly agricultural (grazing, cropping and irrigated pastures) and National Park (Green 2001).

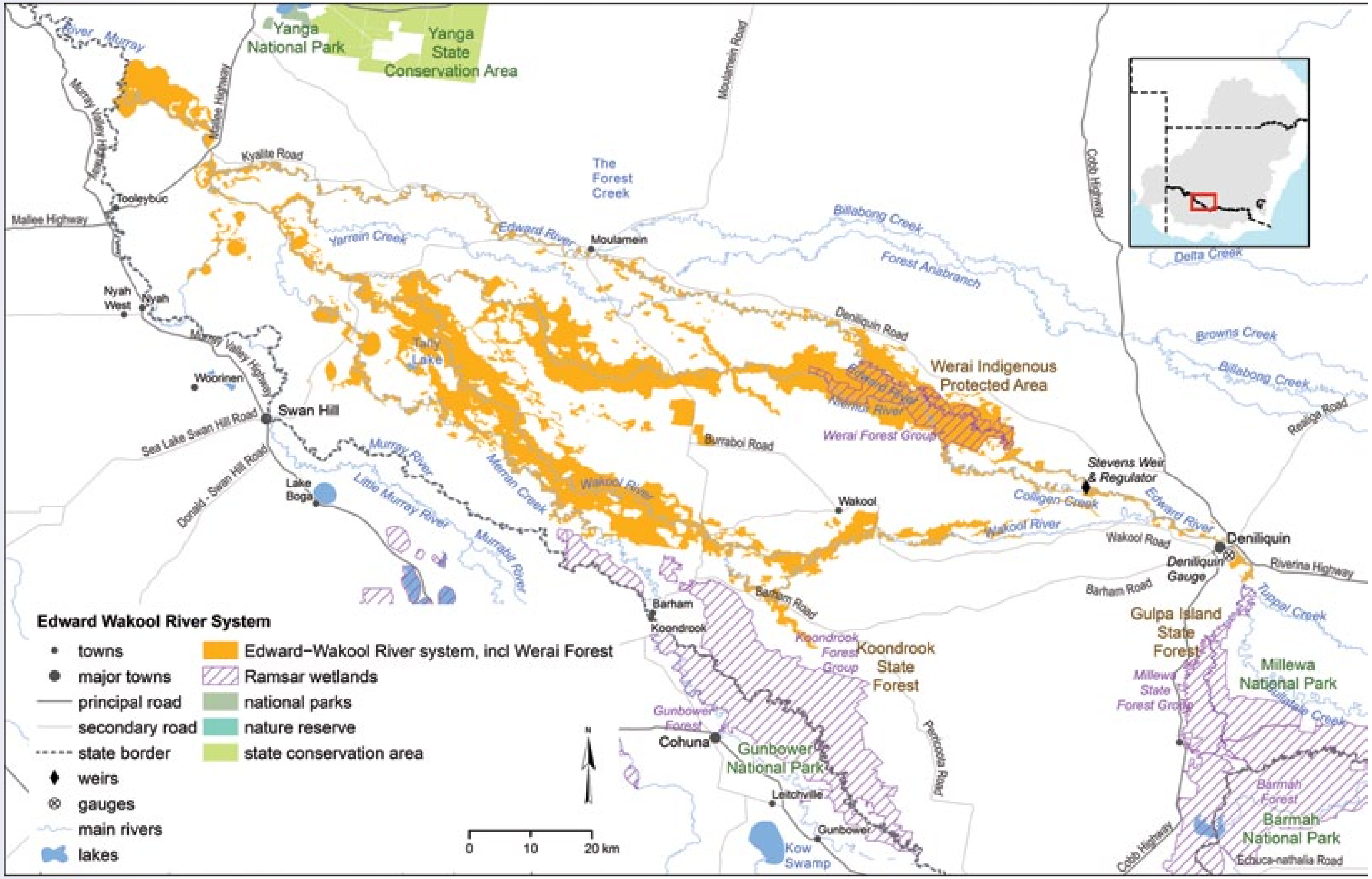

Figure 1: Location of the Edward-Wakool System (MDBA 2010a).

1.3 Overview of river operating environment

The Edward-Wakool system overlaps with the irrigation area supplied by Murray Irrigation Limited (MIL). Murray Irrigation channel flows are highly regulated during the irrigation season from August to May, to deliver water to irrigators throughout the system and to transfer irrigation water around the Barmah Choke to the Lower Murray. The channels are emptied via the escapes in mid-May and the main canals (Mulwala and Wakool) are refilled from mid to late July.

The main source of water for the Edward-Wakool system under regulated flow conditions is the River Murray through the Edward River and Gulpa Creek, and through diversions at Yarrawonga Weir through the Mulwala Canal. Water diverted into the Mulwala Canal can also be delivered back into the natural water courses through "escapes" or outfalls, of which the major escapes discharge to the Edward River, Wakool River and Yallakool Creek. These escapes are also used by MDBA River Murray Operations to bypass the Barmah Choke at times when Murray Irrigation's channels are not running at capacity. This allows River Murray Operations to increase supply to the River Murray downstream of the choke. Other sources of water for the Edward-Wakool system include creeks running through the Millewa Forest such as Toupna Creek, and the effluent streams from the River Murray between Barham and Swan Hill, such as Merran Cutting and Waddy Creek. Billabong Creek, which has its own catchment but also receives water from distributaries of the Murrumbidgee River, can also provide water. A schematic of the system is provided in Figure 2.

The main flow regulating structure within the Edward-Wakool system is Stevens Weir, which is located on the Edward River downstream of Colligen Creek. This structure creates a weir pool which allows water to be diverted down Colligen and Yallakool Creeks and the Wakool River under regulated flow conditions. Colligen Creek is the main supply to the Wakool Irrigation District via the Wakool Main Canal. Flow regulators have been placed on the inlets to the Werai Forest, which allow flow deliveries to be controlled when flow in the Edward River is regulated. Water can also enter the system from the Koondrook-Perricoota Forests via Barbers and Thule Creeks, which discharge into the Wakool River.

Minimum flows are maintained along the Edward River and Gulpa Creek for critical human needs and to maintain irrigation supply, stock and domestic supply, and to maintain water quality (MDBA 2010b). Flows outside of the irrigation season only occur in other rivers in the Edward-Wakool system in response to runoff events. The New South Wales Office of Water has responsibility for maintaining minimum flows in other rivers including the Colligen-Niemur, Wakool-Yallakool and Merran Creek. These minimum flows are not currently documented, as they are managed adaptively.

During flood flow conditions the gates at Stevens Weir are lifted clear of the water, reducing flow impedance. Additional distributary creeks from the River Murray, such as 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 in some locations can be in the order of five times that flowing through the River Murray.

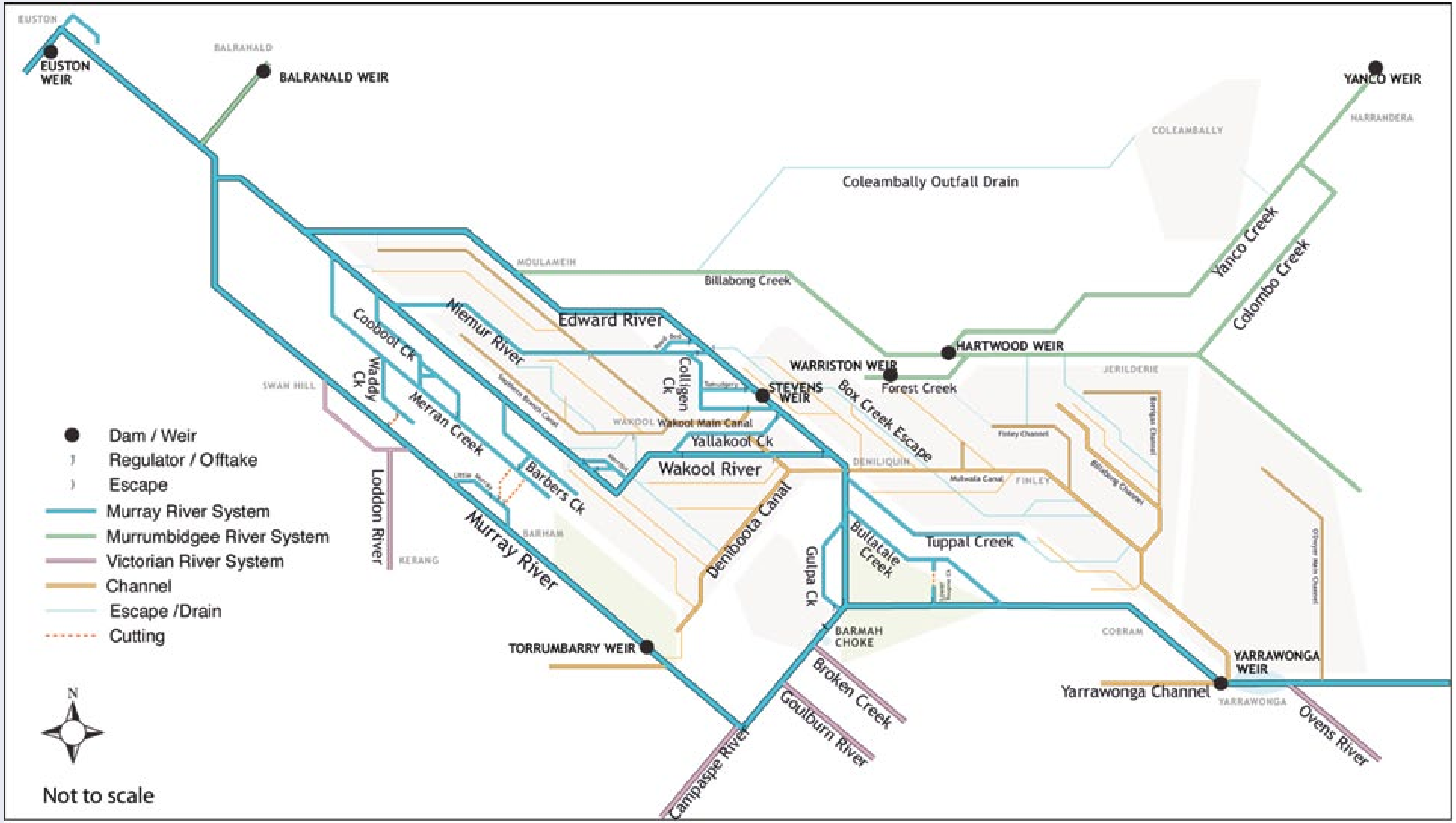

Figure 2: Edward-Wakool River system (adapted from DWE 2009).

2. Ecological values, processes and objectives

2.1 Ecological values

Ecological information for the Edward-Wakool system is limited to only a small percentage of the aquatic ecosystems. Despite this, there are a number of known, significant ecological values within the streams and wetlands of the anabranch system. The system supports over twenty significant flora and fauna species (Appendix A) and is specifically mentioned in the "aquatic ecological community in the natural drainage system of the lower Murray River catchment", which is listed as endangered in NSW.

The system also contains a number of National Parks. This includes Werai Forest which is listed under the Ramsar Convention on Wetlands of International Importance as part of the NSW Central Murray State Forests Ramsar site. Werai Forest covers 11,400 hectares and comprises the greatest extent of river red gum forest and woodland in the system. There are other areas of river red gum (*Eucalyptus camaldulensis*), black box (*E. largiflorens*) and lignum (*Muehlenbeckia florulenta*), particularly along Colligen Creek and the Niemur River, including a 1,600 hectare floodplain wetland within the Murray Valley National Park. However, some of the floodplain areas are hydrologically disconnected from the river by levees (Green 2001). Mature river red gum forest also occurs in the middle reaches of the Wakool River on both private and public land in a riparian strip and patches of wetland forest occur in some intermittent wetlands.

In addition to forested wetlands, there are a number of intermittent and ephemeral streams within the system such as the Tuppal Creek (MCMA 2010) Cockrans/Jimaringle Creeks (Mathers and Pisasale 2010) and Murrian/Yarrien Creek, which when flooded can support a diversity of aquatic flora and fauna. There are also a number of large deflation basins such as Poon Boon Lakes, Lake Toim, Coobool Swamp and Lake Agnes, the latter of which supports large areas of lignum and black box (Green 2001).

The system supports a high proportion of native fish species and is considered to be important in a bioregional context for its role in aquatic species recruitment. In addition, the Edward-Wakool system contains a number of permanent pools that provide drought refuge for native fish (Gilligan et al. 2009) including threatened species such as Murray cod (*Maccullochella peelii peelii*), trout cod (*Maccullochella macquariensis*), Eel-tailed catfish (*Tandanus tandanus*) and silver perch (*Bidyanus bidyanus*).

The asset also includes lagoons and areas of floodplain marsh (Green 2001; Harrington and Hale in prep.), which together with areas of river red gum forest provide habitat for waterbird breeding during periods of sufficient inundation (Harrington and Hale in prep.). Breeding events of hundreds of wetland birds is believed to have occurred in Werai Forests in 2000/01, 2004/05 and 2005/06, although the significance of the site for waterbirds in a regional context remains a knowledge gap (Harrington and Hale in prep.). Most recently, there was a significant breeding event of colonial nesting waterbirds, comprising 1,500 Nankeen night herons and an unknown number of egrets and cormorants in the Murray Valley National Park (Rick Webster, NPWS, pers. comm.).

The environmental values of the Edward-Wakool system have been (and continue to be) impacted by altered hydrological regimes. Altered flow regimes in this asset include (Green 2001; MDBA 2010a):

- a reduction in the frequency of low and no flow events (albeit to a lesser extent than other areas along the River Murray system);
- a rapid rate of rise and fall in channels;
- a reduction in the duration of moderate floods;
- a change in seasonality of flows and a loss of flood pulses important for breeding cues; and
- barriers to fish passage (e.g. Stevens Weir, Yallakool Regulator[1]).

Key threats to the system are predominantly related to altered water regimes and the prolonged drought during the decade 2000 to 2010. There have been reported declines in the condition of wetland-dependent vegetation and a decline in water quality, both of which have affected native fish. Of note is the occurrence of blackwater events as a result of return water from floodplain inundation entering streams and from inundation of litter accumulation in the channel during summer months (Baldwin 2009; Watkins et al. 2010); both of which have led to reported fish kills. Recent investigations have indicated the potential risk associated with acid sulphate soils in wetlands associated with channels of the system (Ward et al. 2010).

2.2 Ecological objectives

Ecological objectives for the Edward-Wakool system have been developed to maintain or improve the condition of key environmental attributes and address significant threats. These are provided in Table 1.

1 Fishway currently under construction

Table 1: Ecological objectives for targeted water use

Broad objective	Location	Ecological Targets
Within channel flows – to provide sufficient ecological baseflow flow and suitable water quality in the regulated streams during dry conditions so they can act as a drought refuges for vulnerable fish, frog and crustacean species; avoid the build-up of organic matter and maintain vegetation health. To provide within channel pulse flows to stimulate productivity and reproduction.	Permanent, semi permanent regulated rivers and creeks (>1,000 km; includes wetlands connected at pool level).	Maintain water quality within channels and pools. Reduce the frequency and magnitude of blackwater events, by preventing the long-term accumulation of litter in channel and on bars and benches.
		Promote productivity to maintain food webs and ecosystem function for in-channel flora and fauna. Maintain connectivity between main channel and lower commence to fill billabongs and backwaters.
		Provide fish passage and allow biota to complete flow driven critical life cycle processes such as spawning, seed setting and dormant stages.
		Maintain inundation of low lying wetlands associated with the river channels to prevent exposure of acid sulphate soils. Known locations include Boiling Downs Creek and Glen Esk-Rusty Waterhole (Ward et al. 2010) but it is highly likely that there are other sites in the system with the same conditions. Aid in floodplain access for wetland specialist fish, frogs and crustaceans.
Flood flows – To reinstate some small and medium floods that provide the flow variability required to improve and restore wetland diversity, resilience and connectivity to the main river channels.	Reed Bed Creek Wetlands (Werai – 400 ha)	Maintain extent and health of reed bed vegetation. Maintain connectivity through the forest (Tumudgery Creek and Reed Beds Creek from Edward River to Colligen-Neimur) between river channel and low lying wetlands for fish and other aquatic fauna.
		Promote successful breeding of waterbirds.
		Provide fish passage and allow biota to complete flow driven critical life cycle processes such as spawning, seed setting and dormant stages.
	River red gum forests (15,000 ha)	Maintain health of river red gum forests and woodlands.
		Promote productivity to maintain food webs and ecosystem function for in-channel flora and fauna. Maintain connectivity between main channel and floodplain.
		Provide fish passage and allow biota to complete flow driven critical life cycle processes such as spawning, seed setting and dormant stages.
		Promote successful breeding of waterbirds.
	Ephemeral wetlands and watercourses	Maintain health of ephemeral wetlands and watercourses (approximately 800 km; includes: Cockran Creek, Yarrien Creek; and Poon Boon Lakes).
	Black Box woodland and depressional wetlands at high elevations.	Maintain the health of Black Box woodlands. Maintain connectivity and promote productivity. Prevent fish stranding and allow biota to complete flow driven critical life cycle processes such as spawning, seed setting and dormant stages.

3. Watering objectives

Watering objectives for the Edward-Wakool system are summarised in Table 2. The objectives reflect the water demands of the asset, as well as incorporating operational constraints and specific ecological requirements. It should be noted that the size and complexity of the Edward-Wakool system presents challenges to quantifying the exact water requirements of the asset and that a number of knowledge gaps remain. As a result, watering objectives will be refined as information availability improves.

The watering objectives for the Edward-Wakool are based on information derived from a number of sources, which are outlined briefly below.

Modelling undertaken by MDBA (2010a) provides a valuable basis for defining watering objectives for the Edward-Wakool. This modeling was primarily based on the ecological requirements of the system – specifically, the water requirements of the major vegetation associations (Figure 3) and colonial waterbirds (Table 3). However, this modeling did not account for the operational constraints inherent in the system.

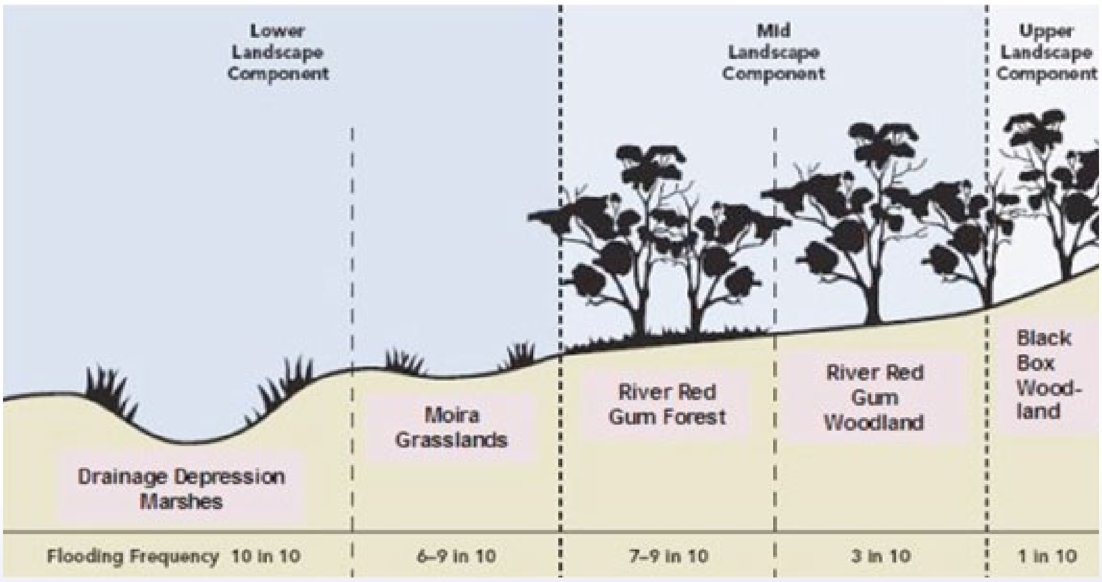

Figure 3: Vegetation associations, geomorphic setting and flood regime (adapted from MDBC 2007 in Harrington and Hale in prep.).

Table 2: Water use management objectives (all flows are quoted for the Edwards River at Deniliquin)

	Management objectives for specific water availability scenarios			
	Extreme dry Goal: Avoid damage to key ecological assets	**Dry** Goal: Ensure ecological capacity for recovery	**Median** Goal: Maintain ecological health and resilience	**Wet** Goal: Improve and extend healthy aquatic ecosystems
Water availability	Minimum allocation on record	30th percentile year	50th percentile year	70th percentile year
Permanent, semi-permanent regulated rivers and creeks (>1,000 km).				
	Minimum of 1,500 ML/day at Deniliquin from mid August to November: Maintain water quality within channels and pools. Reduce the frequency and magnitude of blackwater events, by preventing the accumulation of litter in channel and on bars and benches. Prevent stratification in shallow pools; and ensure stratification in deep pools is not broken. Maintain inundation of wetlands connected at pool level to minimise exposure of ASS. Pulse flow of 2,000 ML/day for 15–30 days in September/October and November – Promote productivity to maintain food webs and ecosystem function for in-channel flora and fauna. Maintain connectivity between main channel and billabongs and backwaters. Augment flows when necessary to ensure rate of fall does not exceed 15 cm / day – Provide fish passage and allow biota to complete flow driven critical life cycle processes such as spawning, seed setting and dormant stages.	Minimum of 1,500 ML/day at Deniliquin from July to November: Maintain water quality within channels and pools. Reduce the frequency and magnitude of blackwater events, by preventing the accumulation of litter in channel and on bars and benches. Prevent stratification in shallow pools and ensure stratification in deep pools is not broken. Maintain inundation of wetlands connected at pool level to minimise exposure of ASS. Two pulse flows averaging 3,000 ML/day at Deniliquin for 15–30 days in September/October and November (noting that this will encompass a rise, a period of flow maintenance and a managed recession) – Promote productivity to maintain food webs and ecosystem function for in-channel flora and fauna. Maintain connectivity between main channel and billabongs and backwaters. Augment flows when necessary to ensure rate of fall does not exceed 15 cm / day – Provide fish passage and allow biota to complete flow driven critical life cycle processes such as spawning, seed setting and dormant stages.	Minimum of 1,500 ML/day at Deniliquin from July to November: Maintain water quality within channels and pools. Reduce the frequency and magnitude of blackwater events, by preventing the accumulation of litter in channel and on bars and benches. Prevent stratification in shallow pools and provide sufficient water to dilute any water quality impacts associated with breaking stratification of deep pools. Maintain inundation of wetlands connected at pool level to minimise exposure of ASS. Two pulse flows averaging 3,000 ML/day for 15–30 days one in September/October and the other in November / December – Promote productivity to maintain food webs and ecosystem function for in-channel flora and fauna. Maintain connectivity between main channel and billabongs and backwaters. Augment flows when necessary to ensure rate of fall does not exceed 15 cm / day – Provide fish passage and allow biota to complete flow driven critical life cycle processes such as spawning, seed setting and dormant stages.	Minimum of 1,500 ML/day at Deniliquin in July, increasing to 4,000 ML/day by mid August through to end November: Maintain water quality within channels and pools. Reduce the frequency and magnitude of blackwater events, by preventing the accumulation of litter in channel and on bars and benches. Prevent stratification in shallow pools and provide sufficient water to dilute any water quality impacts associated with breaking stratification of deep pools. Maintain inundation of wetlands connected at pool level to minimise exposure of ASS. Reconnect refuge holes. Two pulse flows peaking at 10,000 ML/day for 15–30 days in September/October and again November / December – Promote productivity to maintain food webs and ecosystem function for in-channel flora and fauna. Maintain connectivity between main channel and billabongs and backwaters. Augment flows when necessary to ensure rate of fall does not exceed 15 cm / day – Provide fish passage and allow biota to complete flow driven critical life cycle processes such as spawning, seed setting and dormant stages.

	Management objectives for specific water availability scenarios			
	Extreme dry Goal: Avoid damage to key ecological assets	**Dry** Goal: Ensure ecological capacity for recovery	**Median** Goal: Maintain ecological health and resilience	**Wet** Goal: Improve and extend healthy aquatic ecosystems
Water availability	Minimum allocation on record	30^{th} percentile year	50^{th} percentile year	70^{th} percentile year
Reed Bed Creek Wetlands – Werai Forest				
	None	None	5,000 ML/day for 15 days in two pulse flows to supplement a peak in September to October and a second peak in October to November – Maintain extent and health of reed bed vegetation. Maintain connectivity between river channel and low lying wetlands for fish and other aquatic fauna between pulses. Promote successful breeding of waterbirds with short breeding cycles (e.g. ducks and coots). Augment flows when necessary to ensure rate of fall does not exceed 15 cm / day – Provide fish passage and allow biota to complete flow driven critical life cycle processes such as spawning, seed setting and dormant stages.	5,000 ML/day for 120 days from July to December to supplement "natural" peaks during wet conditions – Promote successful breeding of colonial nesting waterbirds. Augment flows when necessary to ensure rate of fall does not exceed 15 cm / day – Provide fish passage and allow biota to complete flow driven critical life cycle processes such as spawning, seed setting and dormant stages. *Note: May not be required if significant inundation has occurred in the previous water year.*

	Management objectives for specific water availability scenarios			
	Extreme dry Goal: Avoid damage to key ecological assets	**Dry** Goal: Ensure ecological capacity for recovery	**Median** Goal: Maintain ecological health and resilience	**Wet** Goal: Improve and extend healthy aquatic ecosystems
Water availability	Minimum allocation on record	30th percentile year	50th percentile year	70th percentile year
River red gum forests (including Werai Forest; Niemur Forest)				
	None	None	None	18,000 ML/day for 10 days to supplement a peak in September to October and a second peak in October to November – Maintain health of river red gum forests and woodlands. Promote productivity to maintain food webs and ecosystem function for in-channel flora and fauna. Maintain connectivity between main channel and floodplain. *Note: May not be required if significant inundation has occurred in the previous water year.*
Black Box woodland / Ephemeral wetlands and watercourses (includes Cockran Creek, Yarrien Creek and Poon Boon Lakes).				
	None	None	None	30,000 ML/day for 21 days to supplement a peak any time between June and December Maintain health of Black Box woodlands, and ephemeral creeks and watercourses. *Note: May not be required if significant inundation has occurred in the recent past. Will be assessed based on inundation history and future ecological requirements.*

In addition to the targets and events described by the MDBA (2010) there is some evidence to suggest that pulse flows, rather than constant flow conditions, may provide better outcomes with respect to fish recruitment (Watts et al. 2009). Collaborative research between the Murray Catchment Management Authority (MCMA), the Department of Sustainability, Environment, Water, Population and Communities (SEWPAC) and Charles Sturt University is investigating the effects pulse flows have on the Edward-Wakool system. Although research into the effects of pulse flows on native fish in Australia is in its infancy, it is thought that even small (in channel) pulse flows can trigger movement of large and small bodied native fish into breeding habitats. Pulse flows also affect food webs, with the first pulse in spring thought to prime large bodied fish for reproduction by stimulating productivity and providing ample food resources. The second pulse then provides the cue for spawning (King et al. 2008; Lyon et al. 2010). Therefore a series of two pulsed flows timed to match seasonal production and breeding requirements may provide the best outcomes for native fish.

There are also some specific water requirements that have been identified to ensure that water quality is maintained and to minimise impacts to fish and other aquatic fauna from increased salinity and temperature; and low dissolved oxygen and pH (Watkins et al. 2010). Principles that have been incorporated into the objectives are:

- Inundation of channels and benches during cooler weather, so that carbon inputs (from leaf litter) can be assimilated into the system and stimulate productivity;
- Avoiding very low flows during peak litter fall (summer), when high carbon concentrations combined with warmer weather (higher temperatures) can lead to blackwater events (Watkins et al. 2010);
- Moderate flows over spring and summer to prevent stratification in shallow pools (e.g. Wakool and Niemur Rivers and Merran Creek);
- Use of operational flows as a means to dilute water returning from floodplains to mitigate the effects of blackwater; and
- Use of operational flows to prevent drying and exposure of acid sulphate soils in wetlands connected at pool level.

Due to substantial knowledge gaps associated with this system, flows provided in Table 3 should be considered indicative only. As more information and knowledge is gained through research and monitoring of flow events, these objectives should be refined to provide more specific details such as target flows at various stages along the system and managed rise and recessions, rather than averages.

Table 3: Nesting habitat and inundation requirements for some species of wetland bird previously recorded breeding in the system (Webster 2008; Briggs 1990; Jaensch 2002).

Species[1]	Stimuli for breeding[2]	Nesting Habitat[3]	Inundation requirements[3]
Little pied cormorant (*Microcarbo melanoleucos*)	Flooding / seasonal	In forks and branches of trees (*Eucalyptus*) and tall shrubs in or over water; sometimes over dry land or on artificial structures.	Minimum depth of 30 to 50 centimetres for sufficient time to prevent nest site becoming dry before nestlings leave nest and reach maturity – three to four months.
White-necked heron (*Ardea pacifica*)	Flooding / seasonal	Low near-horizontal branch of tree in or overhanging water Trees (such as river red gum) fringing river channels, waterholes, lakes and ponds; wooded swamps (such as black box).	Minimum depth of 30 to 50 centimetres for sufficient time to prevent nest site becoming dry before nestlings leave nest and reach maturity – three months.
Great egret (*Ardea modesta*)	Flooding / seasonal	Wooded swamp (such as *Eucalyptus*); high in a tree or tall shrub standing in water, often at a higher site than associated species; on top of lignum shrub; sometimes high in trees on dry land.	Minimum depth of 30 to 50 centimetres for sufficient time to prevent nest site becoming dry before nestlings leave nest and reach maturity – three to four months.
Intermediate egret (*Ardea intermedia*)	Flooding / seasonal	Wooded swamp (such as *Eucalyptus*); high (pp to 15 metres above water) in a tree or tall shrub standing in water.	Minimum depth of 30 to 50 centimetres for sufficient time to prevent nest site becoming dry before nestlings leave nest and reach maturity – three to four months.
Nankeen night heron (*Nycticorax caledonicus*)	Flooding	Wooded swamp (such as *Eucalyptus*); in a tree or tall shrub standing in water, at variable height; often in a discrete zone (encircling a group of breeding egrets); sometimes high in trees on dry land.	Minimum depth of 30 to 50 centimetres for sufficient time to prevent nest site becoming dry before nestlings leave nest and reach maturity – two to three months.
Glossy ibis (*Plegadis falcinellus*)	Flooding	Shrubby swamp (such as. lignum), wooded swamp (such as *Eucalyptus*), and reed/cumbungi beds. In a tree or tall shrub standing in water, usually low in the tree/shrub.	Minimum depth of 30 to 50 centimetres for sufficient time to prevent nest site becoming dry before nestlings leave nest and reach maturity – two to three months.
Australian white ibis (*Threskiornis molucca*)	Flooding / seasonal	Wide variety of habitats used for breeding: typically wooded swamp (such as. *Eucalyptus*), shrub swamp (such as lignum) and reed/cumbungi beds; also exotic wetland and dryland tree copses, bare islands and artificial structures.	Minimum depth of 30 to 50 centimetres for sufficient time to prevent nest site becoming dry before nestlings leave nest and reach maturity – ten weeks to three months (not relevant to nests on dry land).

PART 2:
Water Use Strategy

4. Environmental water requirements

4.1 Baseline flow characteristics

The daily flows anticipated in each month under various climate conditions are presented for the Edward River at Deniliquin (Table 4), Edward River downstream of Stevens Weir (Table 5), the Edward River at Liewah (Table 6) and the Wakool River at Stoney Crossing (Table 7). Deniliquin is the location where environmental flow objectives have been specified in Chapter 2 of this document, whilst Liewah and Stoney Crossing represent end of system flows. Downstream of Stevens Weir is a key location for river operations and delivery to the lower Edward River. This information is sourced from the MSM-Bigmod model of the River Murray system with The Living Murray (TLM) deliveries in place (run #20507), which provides a suitable baseline from which to assess environmental water demand shortfalls. These tables indicate that flow always occurs at Deniliquin, with clear peaks in dry and very dry years during the irrigation season. Flows downstream of Stevens Weir are lower than at Deniliquin because of flows and deliveries to the creeks and canals between the two locations. Flows at Liewah are more variable seasonally and have lower spring flow in wet years than upstream at Deniliquin.

Table 4: Streamflows (ML/d) for the Edward River at Deniliquin (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	44	776	1,534	3,089
Aug	279	1,799	2,860	5,561
Sep	666	2,161	3,717	7,106
Oct	738	2,827	3,970	6,796
Nov	684	2,484	4,075	5,330
Dec	855	2,634	3,279	3,986
Jan	685	2,528	3,145	3,988
Feb	1,363	2,308	3,185	3,805
Mar	636	2,196	2,746	3,772
Apr	348	1,666	1,924	2,173
May	143	894	1,179	1,540
Jun	90	431	634	1,297

Table 5: Streamflows (ML/d) for the Edward River d/s Stevens Weir (1895–2009)

Month	Very dry year (minimum on record)	Dry year (30th percentile daily flow)	Median year (50th percentile daily flow)	Wet year (70th percentile daily flow)
Jul	100	724	1,484	3,002
Aug	100	675	1,954	4,904
Sep	100	799	2457	5,679
Oct	130	599	2,024	4,419
Nov	100	918	2,505	3,814
Dec	100	538	1,226	2,062
Jan	100	314	1,021	1,912
Feb	100	499	1,418	2,038
Mar	145	490	1,307	1,980
Apr	100	411	703	1,155
May	100	400	719	1,097
Jun	100	410	623	1,276

Table 6: Streamflows (ML/d) for the Edward River at Liewah (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	224	911	1,596	2,694
Aug	126	1,116	2,313	4,304
Sep	53	1,244	2,950	5,167
Oct	32	854	2,180	4,117
Nov	108	1,106	2,097	3,116
Dec	3	901	1,675	2,295
Jan	99	769	1,267	1,726
Feb	107	807	1,408	1,878
Mar	131	693	1,333	1,765
Apr	37	594	990	1,433
May	93	646	906	1,194
Jun	217	677	926	1,581

Table 7: Streamflows (ML/d) for the Wakool River at Stoney Crossing (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	64	77	106	716
Aug	66	200	536	3,428
Sep	334	504	1,548	5,824
Oct	352	477	1,160	5,028
Nov	302	422	957	2,220
Dec	282	369	625	1,101
Jan	286	342	405	556
Feb	291	338	403	607
Mar	311	382	448	592
Apr	329	419	446	526
May	290	382	395	419
Jun	126	203	256	315

The relationship between the River Murray downstream of Yarrawonga Weir and the Edward River at Deniliquin requires consideration when planning releases of environmental water from Hume Dam.

Figure 4 illustrates the estimated relationship between the River Murray downstream of Yarrawonga Weir and the Edward River at Deniliquin, based on modelled flows from MSM-Bigmod (run #20507 from 1895–2009 for flows in the River Murray less than 100,000 ML/d). Modelled data was used because the recorded flows at Deniliquin contained significant amounts of missing data in the historical record. Figure 4 shows that the proportion of River Murray water that flows through the Edward River at Deniliquin increases with increasing flow. At the target Deniliquin flows of 18,000 ML/d on average, 38 per cent of River Murray flows are estimated to reach Deniliquin, whilst at the target flow of 30,000 ML/d on average, 50 per cent of River Murray flows are estimated to reach Deniliquin. The flows at Deniliquin have been adjusted for nine days travel time from downstream of Yarrawonga, however this may vary depending on flow rate. For example, travel time is about seven or eight days under regulated conditions and can increase to 12 days during flood conditions.

It should be noted that there is a high degree of uncertainty around these average values. The uncertainty in the relationship at low flows (i.e. less than 15,000 ML/d) is partly due to differences in operation of the Millewa Forest regulators from year to year. When the regulators are open, they can provide flow to the Edward River at River Murray flows between 3,500–6,000 ML/d, but when they are closed they do not commence to flow until the River Murray exceeds 10,500 ML/d. Other sources of uncertainty in the relationship between the River Murray and Edward River flows include:

- differences from year to year in the antecedent conditions in the Millewa Forest and effluent creeks downstream of Yarrawonga;
- streamflow gauging uncertainty;
- differences in the volume of water released through the escapes;
- differences in travel time on rising and falling limbs of flood hydrographs; and
- the influence of backwater effects from the Goulburn River under high flow conditions.

Further information on individual flood peak behaviour is discussed in Section 6.

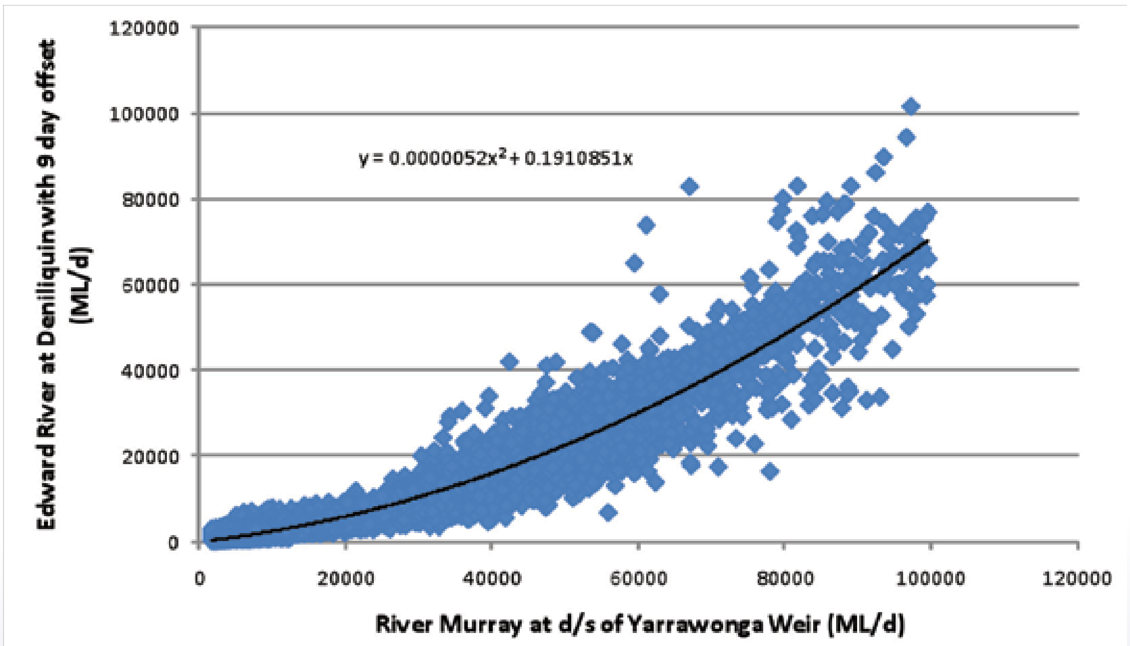

Figure 4: Modelled relationship between flows in the River Murray and Edward River for River Murray flows <100,000 ML/d

4.2 Environmental water demands

In Section 2, there are separate flow targets specified for the permanent, semi-permanent regulated rivers and creeks, the Reed Bed Creek wetlands and the river 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 pulse flows under current river system operation was estimated using data extracted from the MSM-Bigmod model with The Living Murray water deliveries already in place (run #22051). This establishes baseline conditions after delivery of The Living Murray environmental flows. The results of this analysis are shown in Table 8, which indicates that an event of 18,000 ML/d occurs in September/October on average in three years out of every 10 years and that most of these events (2.3 years in 10) are of the desired duration of 10 days. This means that the desired 18,000 ML/d event is likely to occur already in most wet years, but is not likely to occur in median to very dry years.

Table 8: Average recurrence interval for desired pulse flows for Edward River at Deniliquin, 1895–20

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 (years)
Very Dry	1,500 ML/day, 15 Aug – 30 Nov	9.9	5.8	5
	2,000 ML/day for 15 days, Sep/Oct	9.8	9.6	3
	2,000 ML/day for 15 days, Nov	9.6	8.6	3
Dry	1,500 ML/day, 1 Jul – 30 Nov	10.0	2.6	9
	3,000 ML/day for 30 days, Sep/Oct	9.1	4.8	5
	3,000 ML/day for 30 days, Nov	8.1	4.2	6
Median	1,500 ML/day, 1 Jul – 30 Nov	10.0	2.6	9
	3,000 ML/day for 30 days, Sep/Oct	9.1	4.8	5
	3,000 ML/day for 30 days, Nov	8.1	4.2	6
	5,000 ML/day for 15 days, Sep/Oct	6.7	5.0	7
	5,000 ML/day for 15 days, Nov	6.3	4.9	10
Wet	1,500 ML/day from 1 Jul increasing to 4,000 ML/d from 15 Aug – 30 Nov	9.1	0.6	35
	10,000 ML/day for 2 days, Sep/Oct	3.9	3.8	11
	10,000 ML/day for 2 days, Nov/Dec	2.3	2.3	11
	5,000 ML/day for 120 days, Jul–Dec	8.0	1.6	21
	18,000 ML/day for 10 days, Sep/Oct	3.0	2.3	13
	18,000 ML/day for 10 days, Oct/Nov	2.4	2.0	14
	30,000 ML/day for 21 days, Jun–Dec	2.5	1.1	23

The estimated range of volume requirements is shown in Table 9 for each desired event. The triggers for implementing each flow recommendation in this analysis are in line with the operational triggers outlined subsequently in Section 5. Hydrologic analysis is based on static output from MSM-Bigmod. Greater flexibility in delivery rules and improved understanding of the volumes requiring delivery may be possible if these rules are investigated using MSM-Bigmod interactively.

The values in Table 9 represent the potential additional volume to be delivered at Deniliquin and the equivalent volume in the River Murray downstream of Yarrawonga to meet the required event duration above the specified flow threshold. These volumes are in addition to any water delivered under The Living Murray program. The relationship in Figure 4 has been used to convert shortfalls at Deniliquin to an equivalent shortfall at Yarrawonga. This calculation assumes that for River Murray flows less than 10,500 ML/d (maximum regulated flow through the choke) environmental water can be delivered to the Edward River without significant loss, using spare channel capacity in the Edward River, Gulpa Creek and the Murray Irrigation Limited escapes (subject to MIL approval). This spare capacity may not always be available, as discussed in Section 5 on operational delivery constraints, in which case the volume required could be significantly higher.

The volume of water required increases as the climate becomes wetter. For a very dry year, an average of 12,900 ML in the River Murray at downstream of Yarrawonga would be required to maintain winter/spring baseflows and provide the two small fresh events, with the majority of this water (10,000 ML) required for the provision of the baseflows. In a wet year an average of 435,000 ML would be required at downstream of Yarrawonga to provide all of the targeted wet year events. The 5,000 ML/d baseflow creates the largest demand for water in a wet year on average, although the 30,000 ML/d pulse flow creates the largest maximum annual demand. The development of triggers to cease delivering these high flow events could significantly reduce the volumes of water required, particularly when flows are above the operational trigger to commence the event for only a short duration.

It is assumed for the pulses equal to or above 10,000 ML/d that additional water is only required if flows exceed the desired flow threshold under baseline flow conditions. For the 10,000 ML/d event, which is only of one or two days duration, it is assumed that environmental water would be used to increase the flood peak for events near this target volume. For the events equal to and above 10,000 ML/d, which are of longer duration, it is assumed that environmental water would only be used to extend existing events to the desired duration. This is because the desired frequency of events of any duration above the target threshold is already met for recommended median and wet year events above 10,000 ML/d, but the desired duration is not always met at the desired frequency, as shown in Table 8. A falling limb has been added to the environmental water demand hydrographs for the pulses equal to or above 10,000 ML/d. The rate of fall is assumed to be 5 per cent per day for flows above 18,000 ML/d and 10 per cent per day for flows below 18,000 ML/d, based on the examination of falling limb hydrographs in the MSM-Bigmod data at Deniliquin. At these high flows, these rates of rise and fall are based on largely natural runoff events.

The required delivery volume may vary considerably from year to year depending on the ability to forecast flow conditions prior to deciding whether to proceed with the event. The volumes required for the pulse flows in Table 9 are therefore indicative only. Actual volumes required should be based, as best as possible, on MDBA operational model forecasts. For the analysis of the twin winter/spring pulse for Reed Bed Creek in median climate years, the second pulse was assumed to occur after a period of independence of not less than 15 days.

Table 9: Range of additional volumes to achieve desired environmental flows

Climate year	Event	No. of years in 10 event is triggered (across record period)	Volume provided at Deniliquin		Volume provided at Yarrawonga	
			Average volume provided in given climate years (GL/yr)	Maximum volume provided (GL/yr)	Average volume provided in given climate years (GL/yr)	Maximum volume provided (GL/yr)
Very Dry	1,500 ML/day, 15 Aug – 30 Nov	0.9	10.0	43.5	10.0	43.5
	2,000 ML/day for 15 days, Sep/Oct	0.4	0.6	7.5	0.6	7.5
	2,000 ML/day for 15 days, Nov	0.5	1.5	7.5	2.3	14.6
Dry	1,500 ML/day, 1 Jul – 30 Nov	1.8	13.7	38.0	14.0	38.7
	3,000 ML/day for 30 days, Sep/Oct	1.3	7.5	26.9	9.4	36.3
	3,000 ML/day for 30 days, Nov	1.2	9.4	32.9	16.3	79.2
Median	1,500 ML/day, 1 Jul – 30 Nov	1.7	17.4	49.3	17.8	49.3
	3,000 ML/day for 30 days, Sep/Oct	2.0	12.2	34.1	18.3	45.2
	3,000 ML/day for 30 days, Nov	1.9	15.5	36.9	27.5	73.2
	5,000 ML/day for 15 days, Sep/Oct	2.0	21.7	47.4	41.4	124.8
	5,000 ML/day for 15 days, Nov	2.2	16.0	30.0	36.0	97.5
Wet	1,500 ML/day from 1 Jul increasing to 4,000 ML/d from 15 Aug – 30 Nov	4.4	95.2	278.6	134.5	383.0
	10,000 ML/day for 2 days, Sep/Oct	1.1	3.5	25.5	8.3	57.3
	10,000 ML/day for 2 days, Nov/Dec	1.4	4.2	41.8	9.9	80.2
	5,000 ML/day for 120 days, Jul–Dec	3.5	57.1	166.5	121.4	385.4
	18,000 ML/day for 10 days, Sep/Oct	0.9	1.6	34.6	3.0	59.8
	18,000 ML/day for 10 days, Oct/Nov	0.8	2.3	66.1	4.9	152.0
	30,000 ML/day for 21 days, Jun–Dec	1.8	81.1	488.4	152.8	991.6

A summary of the maximum and annual volumes required averaged across all years is shown in Table 10. This table shows that on average 250 GL/yr would be required in the River Murray downstream of Yarrawonga to deliver the desired environmental flows.

Table 10: Range of additional volumes to achieve desired environmental flows across all climate years

Climate year	Deniliquin			d/s Yarrawonga		
	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)	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	55.6	12.1	1.4	55.6	12.9	1.5
Dry	93.9	30.5	6.4	111.8	39.7	8.4
Median	124.6	82.8	15.3	294.7	141.1	26.0
Wet	662.2	245.1	120.4	1,124.5	434.8	213.6
All years	n/a	n/a	143.5	n/a	n/a	249.5

The effect of the proposed environmental flow recommendations on the average and maximum interval between events is shown in Table 11. This table shows, for example, that by using environmental water in the manner proposed, the frequency of years with flows above 3,000 ML/d for 30 days in November would increase from four years in 10 to occurring in all but very dry years (just under nine years in 10). The maximum interval between events is significantly reduced.

Table 11: Change in recurrence intervals under proposed watering regime

Climate year	Event	No. of years in 10 with event of the specified duration		Maximum interval between events (years)	
		Current	Proposed	Current	Proposed
Very Dry	1,500 ML/day, 15 Aug – 30 Nov	5.8	10.0	5	1
	2,000 ML/day for 15 days, Sep/Oct	9.6	9.9	3	1
	2,000 ML/day for 15 days, Nov	8.6	10.0	3	1
Dry	1,500 ML/day, 1 Jul – 30 Nov	2.6	8.9	9	4
	3,000 ML/day for 30 days, Sep/Oct	4.8	9.0	5	4
	3,000 ML/day for 30 days, Nov	4.2	8.8	6	4
Median	1,500 ML/day, 1 Jul – 30 Nov	2.6	8.9	9	4
	3,000 ML/day for 30 days, Sep/Oct	4.8	9.0	5	4
	3,000 ML/day for 30 days, Nov	4.2	8.8	6	4
	5,000 ML/day for 15 days, Sep/Oct	5.0	7.9	7	5
	5,000 ML/day for 15 days, Nov	4.9	7.8	10	8
Wet	1,500 ML/day from 1 Jul increasing to 4,000 ML/d from 15 Aug – 30 Nov	0.6	5.0	35	12
	10,000 ML/day for 30 days, Sep/Oct	3.8	4.7	11	10
	10,000 ML/day for 30 days, Nov/Dec	2.3	3.7	11	11
	5,000 ML/day for 120 days, Jul–Dec	1.6	5.0	21	12
	18,000 ML/day for 10 days, Sep/Oct	2.3	2.7	13	13
	18,000 ML/day for 10 days, Oct/Nov	2.0	2.5	14	14
	30,000 ML/day for 21 days, Jun–Dec	1.1	2.4	23	22

5. Operating regimes

5.1 Introduction

This section presents proposed operational triggers for implementation of the environmental flow recommendations. 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; and
- Identifying any constraints on water delivery, such as available airspace in irrigation channels, 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 the allocation in July, as shown in Table 12. For example, when the high security allocation in July is 100 per cent but the general security allocation is less than 20 per cent, then the recommendations assigned to the dry climate year would be targeted. Allocations have been used as a surrogate for anticipated flow conditions in the Edward River, because the differences in within channel flow in different climate years (previously presented in Table 4) are largely driven by the use of allocations for irrigation supply. If flow conditions change rapidly, such as in a major runoff 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 Edward-Wakool and River Murray, because the flow thresholds for achieving ecological benefits aligned with each threshold, particularly for the higher flow events, are not precisely known at the current time.

For the recommendations associated with bird breeding and inundation of the river red gum forests and black box woodland / ephemeral wetlands, consideration should be given to the time since the last watering event. For example, if a bird breeding event has occurred naturally in the preceding summer period, then the flow recommendations associated with this event in the following winter/spring period may not be needed.

Table 12: Identifying seasonal target environmental flow recommendations

Climate year for selecting flow recommendations	NSW Murray High Security Allocation in July	NSW Murray General Security Allocation in July
Very dry	< 100%	0%
Dry	100%	1–20%
Median	100%	21–40%
Wet	100%	>40%

Using these triggers, the frequency of very dry years is approximately 1.1 years in 10, dry years occur approximately 2.1 years in 10, median years occur approximately 1.8 years in 10 and wet years occur 4.9 years in 10. The modelled frequency of wet years is higher than expected under natural conditions,and further adjustment of these triggers could be undertaken to better refine them. This data is based on using modelled allocations at the start of July, but allocations from mid July could be used if a start of July allocation is not announced.

5.3 Delivery triggers

Proposed operational triggers for delivering the environmental flow recommendations are presented in Table 13.

The delivery of the 1,500 ML/d baseflow in all years occurs continuously over the season specified in the flow recommendations and from the nominated start date. These flows are within channel and can be delivered through the Edward River and Gulpa Creek if not already being provided to meet critical human needs and irrigation demands.

Flow pulses are preferentially provided in response to naturally occurring flow events. The smaller pulses up to 3,000 ML/d are within channel and can be delivered through the Edward River, Gulpa Creek or MIL escapes if not already provided to meet irrigation demands. If these pulses do not occur naturally, a date is specified to trigger delivery within the season specified for the recommendation.

The ability to deliver the flow pulses of 5,000 ML/d are dependent on circumstances in the river system. For the short duration pulses of 15–30 days, they will often occur naturally. Where they do not occur naturally, this peak volume is beyond the channel capacity of the Edward River, Gulpa Creek and MIL escapes. The use of the escapes is dependent on available airspace and incurs additional charges, as explained later in this section. Delivery could be supplemented via the wetland regulators through the Millewa Forest. The use of the Millewa Forest regulators will involve high losses through the forest and would need to occur in harmony with the flow deliveries to the forest. The forest regulators would need to be open to minimise the volume required for delivery of water to the Edward River via this mechanism.

The delivery of the 10,000 ML/d pulse flow at Deniliquin is only of short duration, so where it occurs naturally there is no role to extend it through environmental water deliveries. The threshold for a 10,000 ML/d event at Deniliquin equates to a flow of approximately 29,700 ML/d in the River Murray downstream of Yarrawonga. A trigger for delivery has therefore been arbitrarily set below this value at 20,000 ML/d for environmental watering to increase smaller flood peaks to the desired peak. This watering event needs to occur in conjunction with a Barmah-Millewa Forest watering. Environmental water managers would need to rely on River Murray Operations forecasts of River Murray flow behaviour to estimate anticipated peak flows downstream of Yarrawonga in advance of the release.

Delivery of higher pulse flows (≥18,000 ML/d events at Deniliquin) is triggered by an equivalent flow in the River Murray downstream of Yarrawonga. The 18,000 ML/d event at Deniliquin is estimated to be triggered by a flow of 49,500 ML/d downstream of Yarrawonga and the 30,000 ML/d event at Deniliquin is triggered by a flow of 62,000 ML/d downstream of Yarrawonga. These events are 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 chapter.

Table 13: Summary of operational regime for achievement of environmental objectives

Climate year	Flow objective in Edward River at Deniliquin	Season/ timing	Average return period	Trigger for delivery	Trigger for ceasing delivery
Very dry	1,500 ML/d	15 Aug–30 Nov	All very dry years	Maintain throughout season	n/a
	2,000 ML/d for 15 days	Sep/Oct		Commence delivery if: -- Flow at Deniliquin > 2,000 ML/day; or -- By October 17 Whichever occurs earliest.	n/a
	2,000 ML/d for 15 days	Nov		Commence delivery if: -- Flow at Deniliquin > 2,000 ML/day; or -- By November 16th Whichever occurs earliest.	n/a
Dry	1,500 ML/d	1 Jul–30 Nov	All dry years	Maintain throughout season	n/a
	3,000 ML/d for 30 days	Sep/Oct		Commence delivery if: -- Flow at Deniliquin > 3,000 ML/day; or -- By October 2 Whichever occurs earliest.	n/a
	3,000 ML/d for 30 days	Nov		Commence delivery if: -- Flow at Deniliquin > 3,000 ML/day; or -- By November 1 Whichever occurs earliest.	n/a

Climate year	Flow objective in Edward River at Deniliquin	Season/ timing	Average return period	Trigger for delivery	Trigger for ceasing delivery
Median	1,500 ML/d	1 Jul–30 Nov	All median years	Maintain throughout season	n/a
	3,000 ML/d for 30 days	Sep/Oct		Commence delivery if: -- Flow at Deniliquin > 3,000 ML/ day; or -- By October 2 Whichever occurs earliest.	n/a
	3,000 ML/d for 30 days	Nov		Commence delivery if: -- Flow at Deniliquin > 3,000 ML/ day; or -- By November 1 Whichever occurs earliest.	n/a
	5,000 ML/d for 15 days	Sep/Oct		Commence delivery if: -- Flow at Deniliquin > 5,000 ML/ day; or -- By October 17 Whichever occurs earliest. Trigger flow at Deniliquin is ~20,000 ML/day in River Murray d/s Yarrawonga, depending on Millewa Forest regulator operation	n/a
	5,000 ML/d for 15 days	Nov		Commence delivery if: -- Flow at Deniliquin > 5,000 ML/ day; or -- By November 16 Whichever occurs earliest. Trigger flow at Deniliquin is ~20,000 ML/day in River Murray d/s Yarrawonga, depending on Millewa Forest regulator operation	n/a

Climate year	Flow objective in Edward River at Deniliquin	Season/ timing	Average return period	Trigger for delivery	Trigger for ceasing delivery
Wet	1,500 ML/d increasing to 4,000 ML/d by 15 August	1 Jul–30 Nov	All wet years	Maintain throughout season	n/a
	10,000 ML/d for 1–2 days	Sep/Oct		Commence delivery if: -- Flow downstream of Yarrawonga > ~20,000 ML/day; and -- Flow downstream of Yarrawonga is not expected to exceed 29,700 ML/d naturally.	n/a
	10,000 ML/d for 1-2 days	Nov/Dec		Commence delivery if: -- Flow downstream of Yarrawonga > ~20,000 ML/day; and -- Flow downstream of Yarrawonga is not expected to exceed 29,700 ML/d naturally.	n/a
	5,000 ML/d for 120 days	Jul–Dec		Commence delivery if: -- Flow at Deniliquin > 5,000 ML/day; or -- By September 3rd; Whichever occurs earliest; and -- River Murray d/s Yarrawonga is expected to remain above ~20,000 ML/day for most of season.	Consider ceasing if Murray d/s Y'wonga flow will drop below ~20,000 ML/day for extended period without deliveries.
	18,000 ML/d for 10 days	Sep/Oct		Commence delivery if: -- Flow downstream of Yarrawonga > 49,500 ML/day	n/a
	18,000 ML/d for 10 days	Oct/Nov		Commence delivery if: -- Flow downstream of Yarrawonga > 49,500 ML/day	n/a
	30,000 ML/d for 21 days	Jun–Dec		Commence delivery if: -- Flow downstream of Yarrawonga > 62,000 ML/day	n/a

5.4 Delivery of water for high flow events

The environmental flow recommendations propose 10,000–30,000 ML/d events at Deniliquin in wet years and 5,000 ML/d events in median and wet years. The maximum regulated flow capacity of the combined Edward River and Gulpa Creek offtakes is 2,010 ML/d. However, during the 2010 flood event along the Murray (Figure 5) there was little change in the flow running through the Edward River and Gulpa Creek offtakes, even when the flow in the River Murray downstream of Yarrawonga was as high as 100,000 ML/d.

The flood peak observed in the Edward River at Toonalook, upstream of Deniliquin, is sourced from creeks flowing through the Millewa Forest and effluent creeks upstream of the Edward River offtake. These creeks include Native Dog Creek, Bullatale Creek and Tuppal Creek, amongst others. The commence to flow volumes for these creeks are approximately 3,500–10,500 ML/d for the forest creeks, 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 River Murray downstream of Yarrawonga) (SKM, 2006). Tuppal Creek and Bullatale Creek are continuously gauged for flow. In the 2010 event, Bullatale Creek appears to commence flowing at a much lower River Murray flow than indicated in SKM (2006); however the gauged flow contribution is much smaller than that from the other effluent creeks.

It can also be seen in Figure 5 that Tuppal Creek produces a flood peak after the flow downstream of Yarrawonga exceeds 100,000 ML/d and contributes to the flood peak at Toonalook. In later events in October and November 2010, Toonalook flow peaks three times, presumably due to the ungauged Millewa Forest flows and effluent creeks such as Native Dog Creek. This is because there is no increase in flow running through the Tuppal Creek or the Edward River and Gulpa Creek offtakes when there is a peak at Toonalook. Toupna Creek is the main creek running through the Millewa Forest and has a commence to flow threshold in the River Murray 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 River Murray downstream of Yarrawonga must increase to around 10,500 ML/d for this creek to flow.

The modelled relationship between flows in the River Murray downstream of Yarrawonga and flows in the Edward River at Deniliquin, previously shown in Figure 4, indicate that the Edward River at Deniliquin is around 15–50 per cent of the flow at Yarrawonga. Delivery of high flow events is likely to be more efficient if the regulators in Millewa Forest are open; however at the target flows of 10,000–30,000 ML/d, it is likely that upstream effluent creeks will also flow. At the required flow volumes in the River Murray (approximately 27,000+ ML/d downstream of Yarrawonga), the Barmah Choke will have already exceeded bankfull capacity of 10,600 ML/d measured downstream of Yarrawonga. This means that the Edward River objectives for Reed Bed Creek Wetland and the River Red Gum Forests in median to wet years should be co-ordinated with flooding of the Barmah-Millewa Forest.

Some effluent creeks have been disconnected from the River Murray to protect Tocumwal and surrounding agricultural land from flooding. Better connectivity between the Edward River and the River Murray could be required to more efficiently deliver environmental flows; however this would require significant investigation and on-ground works. Options to improve connectivity between the River Murray and Tuppal Creek are being investigated by Murray CMA (2010) and include constructing a flow regulator through the levee bank and purchasing downstream flood easements.

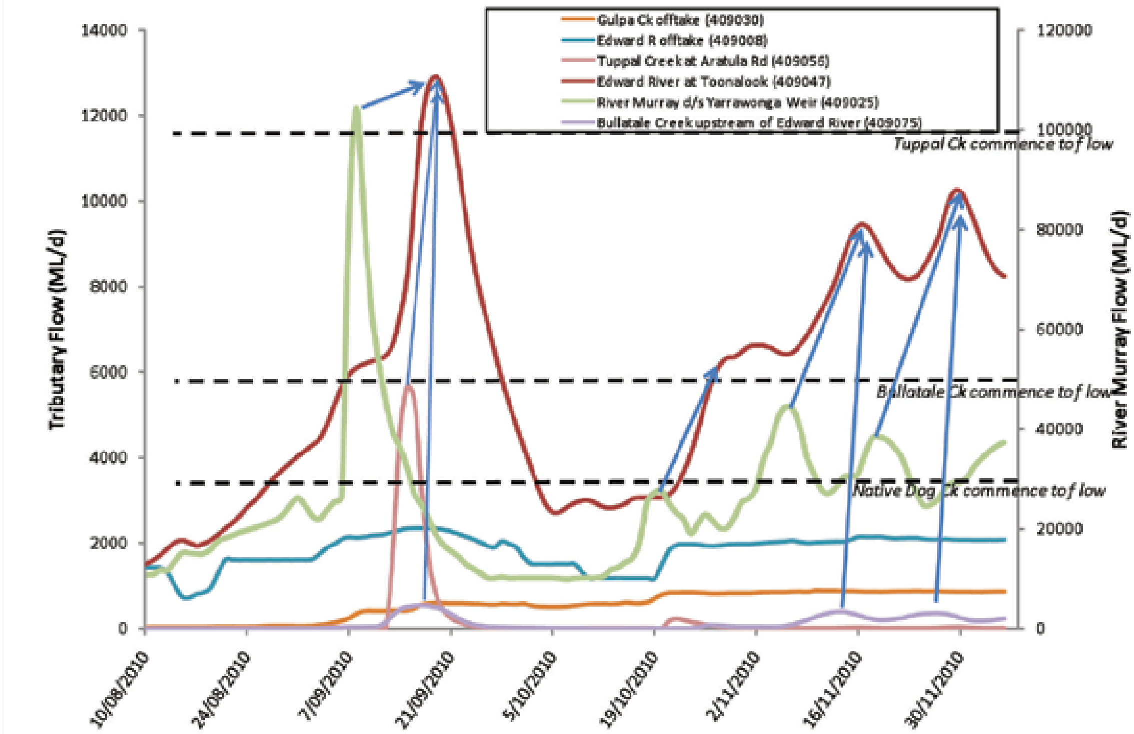

Figure 5: Sources of water during 2010 flood event

In the lower Wakool River, Waddy Creek (to lower Merran Creek) commences to flow at 2,000 ML/d in the Murray River at Barham. Little Merran Creek continued to flow when flow at Barham was only 1,400 ML/d in 2007, which indicates that the commence to flow for this creek is below this value. Both creeks have regulators and Murray River flows to Merran Creek from Waddy and Little Merran were stopped for a few months in 2007 by NSW to gain water savings. The regulated flow along Merran Creek typically ranges from 20–200 ML/d and the maximum regulated capacity at Franklings Bridge is 300 ML/d, above which the St Helena regulator and Erigin Creek Rock Weir are overtopped (MDBA 2010).

5.5 Distributing target Deniliquin flows to downstream rivers

The objectives summarised in Table 3 provide overall flow requirements for the Edward River at Deniliquin. As noted previously in Section 2, there are a number of requirements for water at locations downstream of Deniliquin that need to be adaptively managed by river operators, particularly in relation to water quality objectives. Considerations for water management downstream of Deniliquin have been presented below. This information has been compiled via an iterative process involving stakeholders such as SEWPaC, MDBA, Murray CMA, NSW Office of Water (NOW) and the Office of Environment and Heritage (OEH).

In a very dry year, the recommended minimum flow at Deniliquin is 1,500 ML/d from mid August to the end of November, with a pulse flow of 2,000 ML/d for 15 days in September/October and again in November. The irrigation delivery system may not be operating continuously. Operational factors to be considered in planning the use of environmental water include:

- Edward River flows are likely to be maintained by MDBA river operators, with a 250 ML/d target at Moulamein;
- Keeping Werai Forest regulators closed will improve water use efficiency;
- Wakool River is the last river to be cut off by the NSW Office of Water under low flow conditions. Environmental water could be used to maintain flows of 40 ML/d from August to April and 20 ML/d for the remainder of the year if not otherwise being provided. This should be provided in preference to additional flow along Colligen Creek / Niemur River and Merran Creek; and
- Colligen Creek / Niemur River are the first waterways to be cut off by the NSW Office of Water in conditions of low flow. In the event the NSW Office of Water indicates that they will be ceasing water delivery down the Colligen Creek / Niemur River for water delivery purposes, environmental water releases of 170 ML/d through Colligen Creek would help to prevent build up of organic material.

Key outcomes from the delivery of 30,000 ML of environmental, domestic and stock replenishment flows in the very dry year of 2007/08 are summarised in State Water (2008). The report highlights that if the delivery system has ceased, delivery loss can be minimised when the system is restarted if losses are shared between the environment and stock and domestic users. The notes also illustrate the potential for on-ground interference with flow regulating structures, such as digging trenches to reinstate flows or re-installing drop boards to create a weir pool. Some control sections for streamflow gauges in the Edward-Wakool system have been affected by sediment movement, so environmental water managers should check with the NSW Office of Water about the quality of data being collected in such an event prior to using it for accounting or delivery purposes.

In a dry year, the recommended minimum flow at Deniliquin is 1,500 ML/d from the start of July to the end of November with pulse flows of >3,000 ML/d for 30 days in September/October and again in November. The irrigation delivery system is likely to be operating continuously, but may not be at full capacity throughout the irrigation season. Operational factors to be considered in planning the use of environmental water include:

- Edward River flows are likely to be maintained by MDBA river operators;
- If not already being provided, environmental water could be used to maintain flow down Colligen Creek seven days after delivery of water to the forest, which is the estimated travel time through the forest. Water quality could be maintained by adjusting volume between 170 ML/d, which is the normal operating flow, and 800 ML/d, which is the flow at which water enters flood runners, potentially entraining additional organic material into the creek; and
- Environmental water could be used to maintain water quality in the Wakool River and Yallakool Creek. This could be sourced either from the Wakool River / Yallakool Creek or the Murray River via Merran Cutting or Waddy Creek.

In a median year, the recommended minimum flow at Deniliquin is 1,500 ML/d from the start of July to the end of November with pulse flows of 3,000 ML/d for 30 days in September/October and again in November, as well as 5,000 ML/d in two pulses of 15 day duration from September to November to maintain the Reed Bed Creek wetlands in the Werai forest. The irrigation delivery system is likely to be operating continuously and at full capacity in spring and summer. Operational factors to be considered in planning the use of environmental water include:

- Edward River flows are likely to be maintained by MDBA river operators. Augment flows to ensure rate of fall does not exceed 15 cm/day;
- Open Werai Forest regulators when flows above 3,000 ML/d are being provided based on natural ecological cues. If not already being provided, maintain flow down Colligen Creek seven days after delivery of water to the forest, which is the estimated travel time through the forest. Maintain water quality by adjusting volume above 170 ML/d, which is the normal operating flow, noting that at flows above 800 ML/d water enters flood runners. Flood peaks in excess of this volume may occur naturally during high flow events;
- Environmental water could be used to maintain water quality in the Wakool River and Yallakool Creek. This could be sourced either from the Wakool River / Yallakool Creek or the Murray River via Merran Cutting or Waddy Creek.Environmental water could be provided to ephemeral creeks such as Jimaringle, Cockran, Murrain and Yarrein Creeks; and

In a wet year, the recommended minimum peak flow at Deniliquin is 10,000 ML/d. At these flows Stevens Weir will be drowned out and there will be no capacity to re-direct flows down particular rivers. For the remainder of the year, operational factors to be considered in planning the use of environmental water include:

- Edward River flows likely to be maintained by MDBA river operators. Environmental water could be used ot augment flows to ensure rate of fall does not exceed 15 cm/day;
- If not already being provided, environmental water could be used to maintain flow down Colligen Creek seven days after delivery of water to the forest, which is the estimated travel time through the forest. Water quality could also be maintained by adjusting volume above 170 ML/d, which is the normal operating flow, noting that at flows above 800 ML/d water enters flood runners. Flood peaks in excess of this volume may occur naturally during high flow events;
- Environmental water could be used to maintain water quality in the Wakool River and Yallakool Creek. This could be sourced either from the Wakool River / Yallakool Creek or the Murray River via Merran Cutting or Waddy Creek; and
- Environmental water could be provided for ephemeral creeks such as Jimaringle, Cockran, Murrain and Yarrein Creeks.

5.6 Travel time

The ability to deliver water in response to natural flow events will be affected by the travel time through the system. Travel time information can be used to prepare for the opening and closing of wetland regulators in Werai Forest, for delivering dilution flows and for augmenting natural flow events. It will also affect the ability to co-ordinate deliveries between assets along the River Murray.

The travel time under regulated flow conditions from Hume Dam to Yarrawonga is approximately four days. Travel times through the Edward-Wakool system will vary with flow magnitude and flow route. For example, in the September 2010 runoff event the gauge on Tuppal Creek at Aratula Road peaked around seven days after the Yarrawonga peak. There was no noticeable flood peak at the Edward and Gulpa Creek offtakes, but the gauges at Toonalook, upstream of Deniliquin, and Stevens Weir, downstream of Deniliquin, peaked around 11–12 days after the Yarrawonga peak. The Edward River at Moulamein peaked around 23 days after the Yarrawonga peak, whilst the gauge at Liewah upstream of the River Murray peaked around 27 days after the Yarrawonga peak. That is, it took around 27 days for the flood event to pass through the Edward-Wakool system. Travel times will be longer if passing via the Wakool River and Yallakool Creek. A plot of this event is shown in Figure 6 and a summary of the travel times during this event is shown in Figure 7.

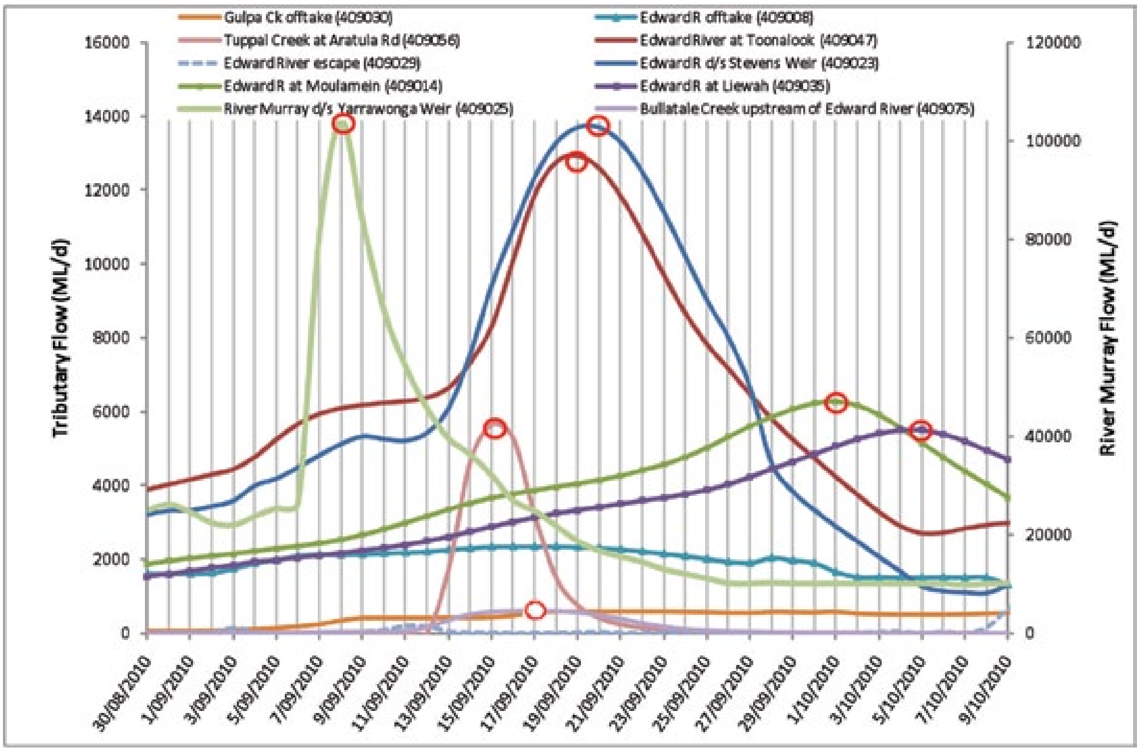

Figure 6: Hydrograph along the Edward River in flood event (Sep 2010)

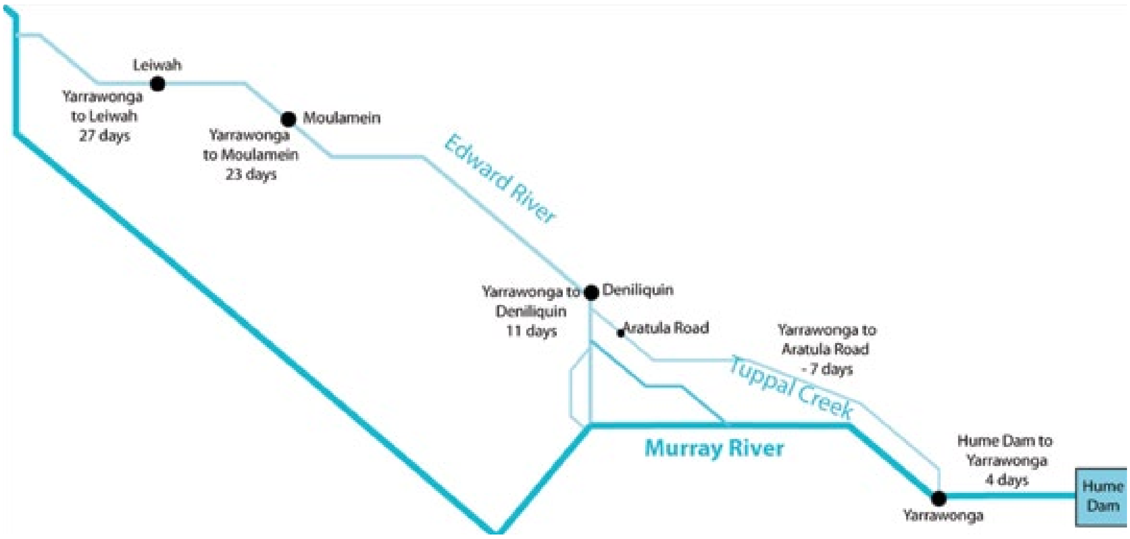

Figure 7: Travel time along the Edward River in flood event (Sep 2010)

5.7 Wetland regulators

There are regulators in place on Tumudgery Creek and Reed Bed Creek in the Werai Forest. The Tumudgery Creek regulator operated at a capacity of up to 120 ML/d in the 2009/10 watering. It temporarily operated at 160 ML/d due to erosion around the regulator which was since repaired. The 'commence to flow' for the Tumudgery Creek regulator (with the gates fully open) is a flow of about 800 ML/day in the Edward River. However, at this flow (or water level) the water only moves into the first few km of the creek and not into the forest. When the Edward River reaches a flow of about 2,100 ML/d (and the gates are open), water starts to flow into the forest. At flows of about 2,900 ML/d, water starts to overtop the regulator (MDBA, 2010). This regulator was built to prevent water entering the forest under regulated flow conditions; however the regulator can also be used to deliver regulated flow if required.

The Reed Bed Creek regulator operates at a capacity of up 90 ML/d, but regulated flow capacity was around 40 ML/d during the 2009/10 watering (MDBA 2010). The commence to flow threshold for the regulator was not available when preparing this report, so should be obtained from forest regulator operators.

5.8 Irrigation channel operation

There is the possibility of providing part of the environmental water for the lower flow recommendations (up to 5,000 ML/d) through the Edward River and Gulpa Creek offtakes, and through the Murray Irrigation channel escapes. Each of the escapes is drained at the end of the irrigation season, which may provide increased capacity for environmental water delivery. For example, in 2009 the volume of water drained from the escapes included 7,000 ML drained from the Edward Escape and under 2,000 ML from the Wakool, Yallakool, Perricoota and Finley Escapes (MDBA 2010). The capacity of various channel offtakes and escapes is listed in Table 14.

Table 14: Irrigation delivery capacities under regulated flows (MDBA 2010)

Location	Capacity (ML/d)
Edward River offtake	1,660
Gulpa Creek offtake	350
Gulpa Creek offtake when making deliveries to Reed Bed Swamp (Millewa forest)	750
Mulwala Canal offtake (from Yarrawonga Weir)	10,000
Edward Escape (from Mulwala Canal to Edward River)	2,400
Edward Escape (from Mulwala Canal to Edward River) during irrigation season to allow for rain rejections	2,100
Lawson's Siphon (Mulwala Canal under Edward River)	2,500
Wakool Canal	2,350
Wakool Escape (from Mulwala Canal to Wakool River)	500
Perricoota Escape (from Deniboota Canal to Torrumbarry Weir Pool)	200
Yallacoota Escape (from Mulwala Canal to Yallakool Creek)	80
Finley Escape (from Finley Channel to Billabong Creek)	250

The Murray Irrigation channel system is generally operated at full capacity in October to establish rice crops and again in February/March for winter pasture/rice maintenance, but does not operate at capacity in low allocation years (Green 2001). The movement of water entitlements out of the Edward-Wakool system may reduce the use of the channels in the future. During the irrigation season, the MIL system is also used by the MDBA to bypass the Barmah Choke through Mulwala Canal and the Edward River (via the Edward Escape).

The likelihood of spare capacity being available in the channel system for delivery of water through the escapes was examined using the MSM-Bigmod version with The Living Murray deliveries in place (run #20507). This version of the model provides the best readily available representation of conditions prior to the implementation of environmental flows. The minimum, maximum, median, 10th and 90th percentile channel capacities in each month of the year over the modelling period 1895–2009 are presented for each of the four climate conditions in Figure 8 for the Edward Escape. Edward Escape is by far the largest escape and the most likely to be able to deliver the required shortfall volumes to meet ecological objectives. The outcome from this analysis of Edward Escape is that:

- in a very dry year the channel system does not operate at full capacity and there was generally spare capacity during the winter/spring period in excess of 1,500 ML/d;
- in dry years, capacity was sometimes limited in summer/autumn, but capacity was generally available up to around 2,000 ML/d in winter/spring;
- in median years there was generally less than 1,000 ML/d available in the summer/autumn period and no capacity available in August at least 10 per cent of the time; and
- in wet years there was more channel capacity available early in the irrigation season than in median years, but available capacity was limited to less than 1,000 ML/d in summer most of the time. In some wet years the channels are operated at capacity to provide dilution flows during black water events, however this operational behaviour is not modelled in MSM-Bigmod and any flows delivered for this purpose would be in addition to those used to derive Figure 8. Spare capacity is also likely to exist in practice during periods of rainfall, when some irrigators do not take their ordered water.

All monthly statistics in Figure 8 are based on a minimum of 30 data points for each month.

A similar plot has been prepared for Mulwala Canal offtake in Appendix B. The data for Mulwala Canal offtake shows that in a very dry year there is likely to be spare capacity in the canal well in excess of the Edward Escape capacity. In dry to wet years the spare capacity in the canal decreases at the height of the irrigation season and in some years the spare capacity from November to March can be less than the Edward Escape capacity. This means that the offtake capacity of Mulwala Canal may occasionally be a constraint to using the Edward Escape to deliver environmental flows over these months, but will generally not be a constraint. Data for other escapes was not readily available from MSM-Bigmod.

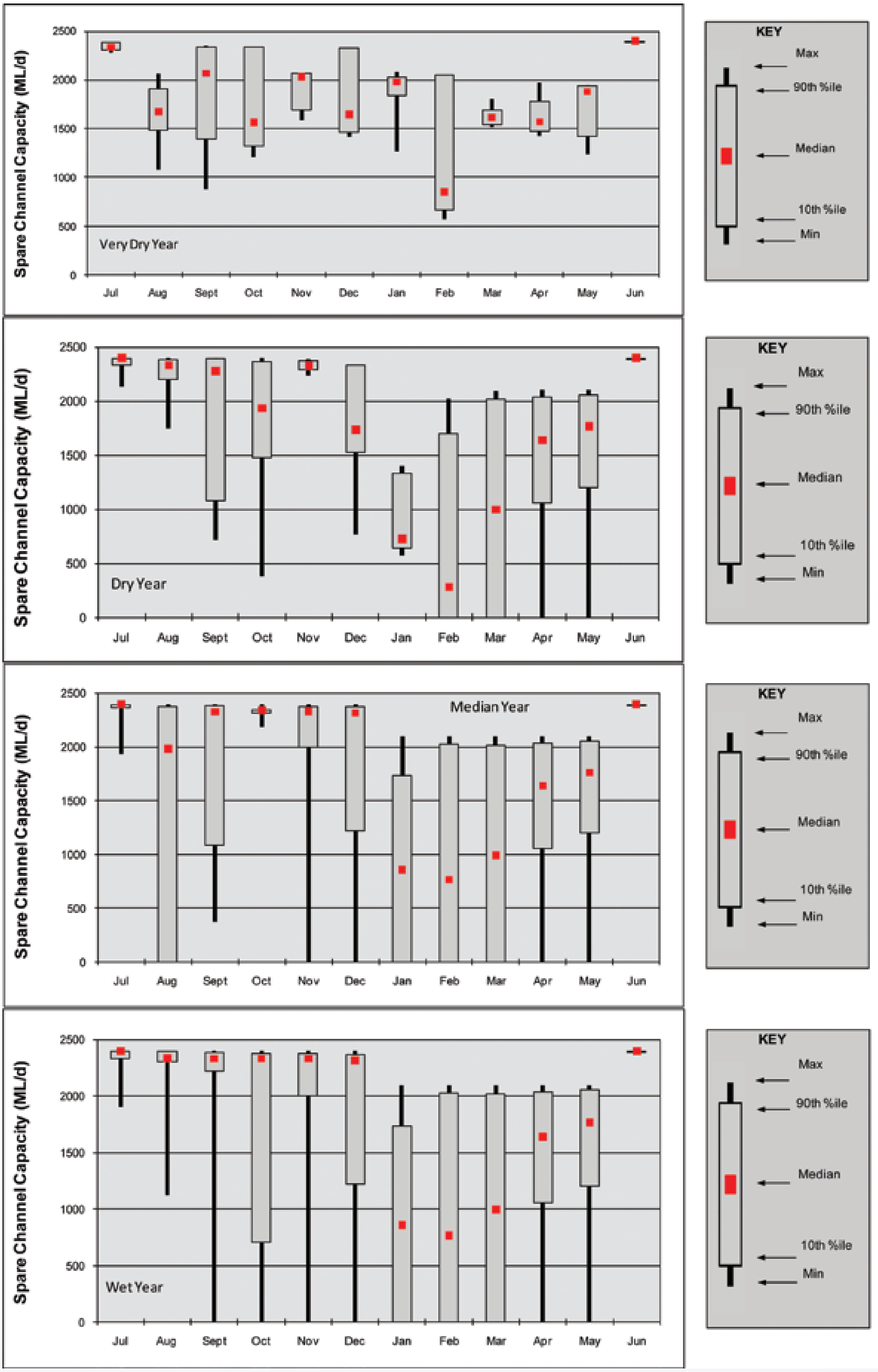

Figure 8: Spare channel capacity in Edward Escape, 1895–2009 (min, 10th percentile, median, 90th percentile and maximum daily values)

5.9 Flooding

Releases from Hume Dam are constrained to 25,000 ML/d (gauged at Doctors Point) under regulated flow conditions. Releases from the dam above this volume cause water levels to rise above flood easements and onto private property downstream of the dam. While releases above 25,000 ML/d are possible (and have been made historically), impacts to landholders require consideration. For example, damage to pasture grass generally occurs after inundation for five days or longer.

The River Murray channel has a capacity of 62,000 ML/d downstream of Yarrawonga Weir. Yarrawonga Weir is not expected to be a constraint on the delivery of environmental flows to the Edward-Wakool system.

Flooding in the Edward-Wakool system needs to be carefully managed at various points in the system under regulated flow conditions. The following issues require consideration in the delivery of large volumes of environmental water to the Edward-Wakool:

- The Edward River channel capacity downstream of Stevens Weir is 2,700 ML/d, above which water starts to flow over the top of the regulators (Junction regulator at the Niemur River) in the Werai Forest (MDBA 2010). This is not a constraint when intentionally delivering environmental flood flows.
- Colligen Creek is normally operated at 170 ML/d in summer. At above 800–850 ML/d water spills into lagoons and creek runners, which has been historically avoided to minimise losses when supplying regulated flow (MDBA 2010). Flows in excess of 500 ML/d can start to cause low level flooding in the low lying areas along the Niemur River downstream of Moulamein Road (Col Hood, State Water, pers.comm. March 2011).
- The Wakool River offtake from Stevens Weir operates at 150 ML/d, with the Wakool escape adding up to a further 500 ML/d. Low level road crossings are overtopped and some landholders might lose access when the Wakool River exceeds 200–300 ML/d (MDBA 2010).
- The Yallakool Creek offtake from Stevens Weir has a capacity of 600 ML/d, but low level road crossings are overtopped and some landholders might lose access at flows above 200 ML/d (MDBA 2010).
- The area downstream of the Yallakool Creek and Wakool River confluence known as Bookit Island can be subject to flooding. Farmers can lose access to roads into farms at around 500 ML/d and are unable to harvest crops when flows exceed around 1,000 ML/d (John Conallin, Murray CMA, pers.comm. March 2011). This figure will need to be confirmed with State Water.
- The regulated flow range of Merran Creek is 20–200 ML/d. The channel capacity at Franklings Bridge (upper end of Merran Ck) is 300 ML/d because at higher flows the St Helena regulator and Erigin Creek Rock Weir are overtopped (MDBA 2010).

5.10 Storage releases

The release capacity of Hume Dam is well in excess of the downstream constraints on releases due to flooding of private land. Current easements allow the passing of 25,000 ML/d along the reach between Hume Dam and Lake Mulwala. Releases above 25,000 ML/d have been made historically, including for the delivery of environmental flows, and were still well below the release capacity of the storage. 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.

5.11 Weir flow control

Stevens Weir is not a constraint on the delivery of environmental flows. The weir can be operated to control low flows and can be removed during high flow events.

The Wakool River offtake from Edwards River (Stevens Weir pool) occurs at an elevation of 4.5 m, which is within the normal operating range for the weir pool under regulated flow of 4.5–5.2 m. Yallakool Creek commences to flow at an elevation of 3.5 m which is below the minimum operating level of Stevens Weir pool (MDBA 2010). Colligen Creek commences to flow at an elevation of 3.0 m and the Wakool River offtake commences to flow at an elevation of 4.0 m (Col Hood, State Water, pers.comm. March 2011).

Stevens Weir pool is drained annually, usually commencing from 1–15 May and re-instated from 1–15 July, depending on the end of MIL's irrigation season and the off-season works program. Small freshes are allowed to pass through as natural events when the weir pool is empty (Col Hood, State Water, pers.comm. March 2011).

5.12 Recreational users

Stevens Weir pool is used for recreation and the Edward River is used for recreational fishing, boating and kayaking along its length.

5.13 Water delivery costs

5.13.1 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 on the water diverted at Yarrawonga Weir (based on the Memorandum of Understanding between MIL and NSW State Water).

Any water sourced from Victorian water shares for delivery to the Edward-Wakool system would first be transferred to a NSW Murray system account and then State Water's delivery costs would apply.

5.13.2 Regulated river water management charges

The NSW Office of Water 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 use 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.

5.13.3 Carryover costs

State Water does not charge for carryover.

Goulburn-Murray Water charges 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 $3.25/ML for the Murray system. See http://www.g-mwater.com.au/customer-services/carryover#1 for more information.

5.14 Interactions with other assets

As discussed earlier in this section, the Edward-Wakool system is linked to the River Murray from Yarrawonga Weir to the Barmah-Millewa Forest. Delivering the desired flood flows in median and wet years to the Edward-Wakool system will also flood the Barmah-Millewa Forest. This is because the commence to flow for effluent creeks that can deliver major flood flows through the Edward-Wakool system are generally higher than the commence to flow for effluent creeks through the Barmah-Millewa Forests. Some flood runners through the Millewa Forests will contribute to the Edward River at flows as low as 5-10,000 ML/d in the River Murray downstream of Yarrawonga.

The Edward-Wakool system is linked to the Goulburn, Campaspe and Loddon Rivers via the effluent creeks in the River Murray from Barmah to Swan Hill, which feed into the lower Wakool system. Flows from these tributaries can supply the Lower Wakool River and the Merran Cutting. Similarly, water from the Koondrook-Perricoota Forest can interact with the lower Wakool River via effluent creeks near Barham and downstream ecological assets on the River Murray, such as the Lindsay, Mulcra and Walpolla Islands. Some of these effluent streams are permanently connected to the River Murray.

The Edward-Wakool system is connected to the lower Murray as the Wakool and Edward Rivers outfall downstream of Swan Hill. As such, flows from the Wakool and Edward Rivers may contribute to watering of downstream sites such as the Hattah Lakes and Lindsay-Wallpolla Islands.

6. Governance

6.1 Delivery partners, roles and responsibilities

The major strategic partners in delivering water to assets within the Edward-Wakool system include:

- OEH as the manager of the Adaptive Environmental Water in the Water Sharing Plan for the NSW Murray and Lower Darling Regulated Rivers Water Sources.
- MDBA as the operator of the Murray system releases from Hume Dam.
- SEWPaC as responsible for development and implementation of national policy, programs and legislation to protect and conserve Australia's environment and heritage.
- CEWH as responsible for management of water entitlements that the Commonwealth Government acquires to be used to protect or restore environmental assets.
- Murray Irrigation Limited and NSW State Water Corporation as operators of the Murray Irrigation channels and escapes.
- NSW State Water Corporation and NSW National Parks and Wildlife Service as operators of the flow regulators into and out of Werai Forest.
- Murray CMA as a stakeholder in the development and implementation of watering plans.
- Department of Sustainability and Environment (DSE) and OEH as holders of water for the Barmah-Millewa accounts.
- NSW Office of Water.

6.2 Approvals, licenses, legal and administrative issues

6.2.1 Water shepherding and return flows

Estimation of the volume of return flows in the 2009/10 watering of Werai Forest is documented in MDBA (2010). Manual gaugings were taken at the Tumudgery and Reed Bed Creek regulators. It was estimated that 4,700 ML was delivered through Tumudgery Creek regulator and 2,200 ML was returned for a net volume used of 2,500 ML. Reed Bed Creek wetlands received 2,600 ML less 1,800 ML return flow, which is a net of 800 ML. An additional 500 ML was assumed to cover higher "losses" in the Colligen-Niemur Rivers. However, the return flow arrangements for the 2009/10 watering events were 'one-off' arrangements. Return flow arrangements for future events may be based on modelled estimates of environmental use. Robust procedures for estimating return flows associated with the delivery of water to Werai Forest in 2010/11 are being developed by the Murray CMA and expected to be available in mid-2011 (John Conallin, Murray CMA, pers.comm. November 2010).

Section 45 of the Water Sharing Plan for the NSW Murray and Lower Darling Regulated Rivers Water Sources (currently suspended but scheduled to recommence from 1 July, 2011) 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 NSW Minister for Primary Industries 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 yet. Until such time as this policy is finalised, the process by which return flows could be granted would be for environmental water managers to apply to the NSW Minister for Primary Industries for the relevant licence to be re-credited.

Gaining credits in the River Murray downstream of the Edward River would again require an application to the NSW Minister for Water, which would allow any environmental water delivered to be reused to the end of the Water Sharing Plan area at the South Australian Border. Gaining credits at this location could require agreement of NSW, Victoria and South Australia.

Applications for credit of return flows is likely to be more successful if the application is received prior to the watering event and secondly if the watering event occurs under unregulated flow conditions, such as when supplementing a natural flood in the Edward-Wakool system. Under unregulated conditions there is less potential for reuse by consumptive users and therefore less potential for conflict over access to the returned water.

The existing operating rules for the River Murray system (contained in the accounting rules for "Edward System Losses") can create a disincentive for NSW (and River Murray Water) to operate the Edward-Wakool system for improved environmental outcomes. The existing rules penalise NSW for losses in the Wakool River rather than sharing losses between all jurisdictions, as is the case for flows passing through sections of the River Murray and Edward River that parallel the Wakool.

6.3 Trading rules and system accounting

6.3.1 Water trading

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

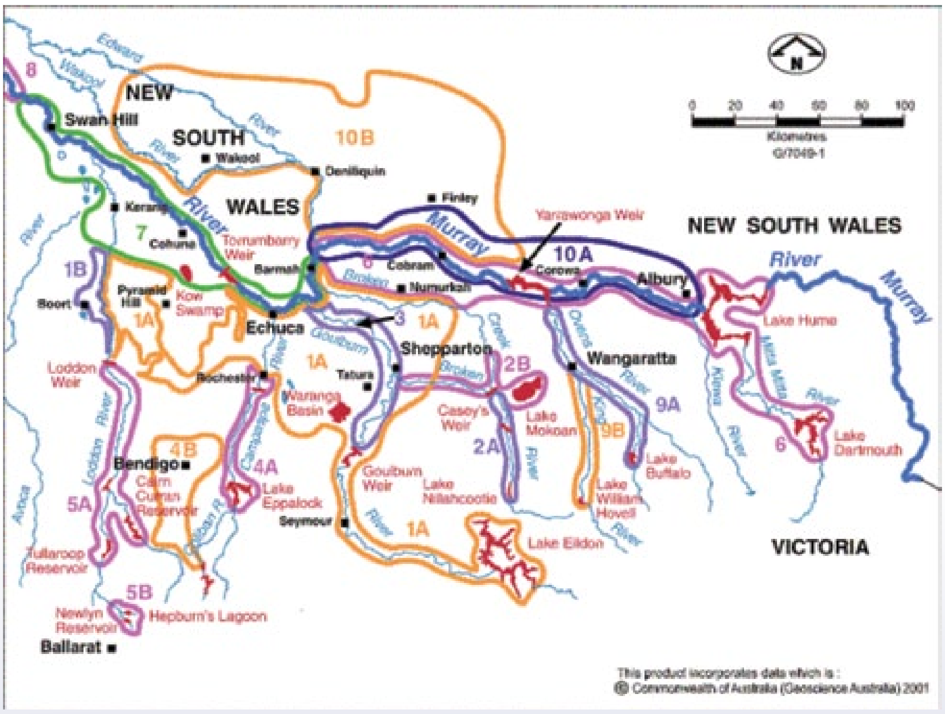

Figure 9: Trading zone boundaries (source: http://www.watermove.com.au)

The Edward-Wakool system is located in Trading Zone 10A (NSW Murray above Barmah). Water shares from this trading zone 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) attracts a 10 per cent forfeit of share volume. This 10 per cent forfeit only applies when using the Murray Irrigation Limited channel system to deliver water and does not apply to water delivered via rivers (D.Jacobs, OEH, 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), 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 four 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 River Murray 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, 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; and
- Intrastate – 90 per cent of allocation trades processed within five business days.

This means that any allocation trades must be completed 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 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.

6.3.2 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 has been suspended since 2006 due to on-going dry conditions but is scheduled to recommence 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, carryover is the first to spill. Annual deduction for evaporation is five per cent of carried over volume. The fee for transferring water from the spillable water account back to the allocation bank account is $3.25/ML for the Murray system. See http://www.g-mwater.com.au/customer-services/carryover#1 for more informat

For more information on carryover, see http://www.g-mwater.com.au/customer-services/carryover/lbbcarryover/. DSE is currently reviewing these arrangements.

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

6.4 Water use plans

While there is no environmental flow determination or dedicated environmental water allocation plan for the Edward-Wakool system, it is identified as a hydrological indicator site by the MDBA (MDBA 2010a). In addition, there are two watering plans that include the Edward-Wakool system; Water Sharing Plan for the New South Wales Murray and Lower Darling Regulated Rivers Water Sources (DWE 2003) and Murray Adaptive Environmental Water Plan 2010–2011 (OEH 2010). These offer broad water objectives for the NSW Murray Catchment that are of relevance to the Edward-Wakool system (see section 2.1 above).

The environmental water provisions in the Water Sharing Plan for the New South Wales Murray and Lower Darling Regulated Rivers Water Sources 2003 (suspended in 2006 but scheduled to recommence from 1 July 2011) are implemented by the NSW OEH. The plan sets out provisions for planned environmental water (Barmah-Millewa Allowance, Barmah-Millewa Overdraw, Lower Darling Environmental Contingency Allowance, and a Murray Regulated River Water Source Additional Environmental Allowance and Adaptive Environmental Water). Of these, only the Murray Regulated River Water Source Additional Environmental Allowance and Adaptive Environmental Water are of relevance to Edward-Wakool system.

OEH intends to produce an Annual Watering Plan for each regulated water source in which they have a decision making role. This Watering Plan will cover the use of Environmental Water Allowances and any NSW licences nominated as Adaptive Environmental Water. The current plan covers the period 2010–2011 (OEH 2010). During the 2009–2010 season, the Murray Lower Darling Environmental Water Advisory Group (MLD EWAG) was established to provide advice on the management of environmental water within the NSW Murray Valley.

7. Risk assessment and mitigation strategies

Potential risks of delivering environmental water to the Edward-Wakool system have been assessed according to the SEWPaC risk assessment framework (see Appendix D) and are summarised in Table 15. The risk assessment provides an indication of the risks associated with the delivery of environmental water in the Edward-Wakool 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 quoted are the unmitigated risks, i.e. the risk from the event in the absence of adaptive management.

Conditions in the Edward-Wakool River in recent years have led to a number of serious impacts, particularly to the native fish community. If not managed properly, there is a risk to native fish from:

- Increased salinity (washed from the hypolimnion of deep pools when stratification breaks down);
- Increased acidity from wetting of previously exposed acid sulphate soils;
- Low dissolved oxygen (expanded on below);
- Fish stranding on the floodplain when water levels recede too rapidly;
- Lack of water – drying into series of pools; and
- Invasive species such as carp.

At low flows and cease to flow, salinity can increase in the Wakool, Niemur and Merran. This is managed by releasing fresher water in the Edward and trying to keep Murray flow high when a salinity spike from the Wakool is on its way to the Murray. State Water and/or the MDBA issue warnings to landholders along the Wakool if high salinities occur (MDBA 2010).

Low dissolved oxygen in the streams of the Edward-Wakool system can occur via a number of pathways. Releases of water from floodplain forests (Werai, Barmah-Millewa and Koondrook-Perricoota) can result in low dissolved oxygen blackwater events as organic matter on the floodplain surface is rapidly metabolised by microorganisms (Baldwin 2009; Gilligan et al. 2009). Build up of litter in channel and on benches is also sufficient to result in blackwater upon inundation, if not managed properly (Watkins et al. 2010). Investigations into acid sulphate sediments in wetlands along the Edward-Wakool system (Ward et al. 2010) have indicated high monosulphide concentrations in surface soils, which represent a high risk of deoxygenation after prolonged wet conditions. Rapid flows after a period of dry conditions can break stratification and release deoxygenated water from the bottom layers of deep in channel pools (Baldwin 2009).

The risk to native fish (and other aquatic fauna) from low dissolved oxygen may be mitigated by careful management to ensure sufficient flushing flows to prevent the build up of litter in channel and by timing water releases to occur at lower temperatures. Watkins et al. (2010) recommend continuous flows prior to and during times of peak litter fall (summer) to prevent the build-up of organic matter in channels. This continuous flow during warmer months would also prevent prolonged stratification in shallow waterholes.

Keeping sufficient flows in the Gulpa Creek and Edward River main channel, as well as keeping the Edward River escape open, will help to mitigate this.

Fish stranding on the floodplain and in billabongs and backwaters can be prevented by ensuring that water levels do not drop rapidly. This may mean the use of environmental water to moderate flood recessions and maintain rates of fall to less than 10-15 centimetres per day. This would also benefit other aquatic fauna and flora by providing time for egg-laying, seed setting and preparing other dormant life-cycle phases.

Environmental flows may also result in an increase in the abundance and diversity of invasive species within the system. Carp (*Cyprinus carpio*) are already present in the system, and experience from adjacent areas such as Barmah-Millewa has shown that floodplain inundation can favour carp spawning and recruitment (Stuart and Jones 2002). In addition, floodwaters can carry propagules for invasive plant species. Although this is a knowledge gap for this system, it is possible that native macrophytes could be displaced by invasive species such as arrowhead (*Sagittaria graminea*), which is known from the Edward River, and could be dispersed further through the system. However, the increased risk from environmental water delivery (above normal river operations) on the spread of invasive species is unknown. Weeds such as arrowhead, which require permanent water, may already be distributed through suitable habitat in the system and would not survive periods of dry, if transported into intermittent and ephemeral streams and wetlands.

Other potential risks are to waterbird breeding. Any inundation of large wetland areas (such as Reed Bed Creek in Werai Forest) can act as a stimulus for the onset of breeding. If inundation is of insufficient duration or water levels recede too rapidly, nests can be abandoned and breeding unsuccessful. This will require adaptive management to ensure that if a large scale breeding event commences, water is retained in wetlands and feeding areas long enough for successful fledging.

Table 15: Risk associated with water delivery in the Edward-Wakool system

Risk type	Description	Likelihood	Consequence	Risk level	Mitigation
Acid sulphate soils	Acid sulphate soils have been detected in wetlands along the Edward and Wakool Rivers. Although the risk of acidification from eight wetlands examined was low, there was a moderate risk of acidification from three wetlands (Ward et al. 2010). It should be noted that the risk of mobilisation of metals was low for all sites surveyed.	Likely	Minor	Medium	Ensure adequate flushing flows to dilute any potential effects of low pH water entering stream environments from inundated wetlands.
Salinity	Salt water can wash from the bottom of deep pools if stratification develops and then is broken by sudden high flows.	Likely	Minor	Medium	Continuous flows during summer months.
Invasive species	Carp breeding is likely to be favoured by large flow events in Werai State Forest.	Likely	Minor	Medium	Flow options for disruption of carp spawning can be investigated. However, any measures would need to maintain native fish spawning.
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 floodwaters are returned to streams of floodplain surfaces.	Likely	Major to minor depending on event type, location and timing	High	Careful monitoring and adaptive management, particularly when waters are entering streams from floodplain surfaces. Can also be minimised by instigating floodplain inundation in cooler months. Manage flows in channel to prevent build up on in stream litter.
Water loss	Water may not reach intended target if (i) Millewa Forest regulators are closed or (ii) if Millewa Forest is dry prior to delivery of events or (iii) if escapes are to be used and consumptive users access the water.	Unlikely	Minor	Low	Communicate with OEH and MIL prior to delivery of water to ensure appropriate volumes are released for the current conditions.
Fish stranding	A rapid fall in water levels (as occurred this year) can lead to a loss of recruitment of both fish and waterbirds, with potentially significant effects to populations that are already stressed from drought.	Possible	Moderate	Medium	Manage flows to prevent rate of fall from exceeding 15 centimetres per day.
Unsuccessful recruitment of fish	Inappropriate delivery of pulses, or number of pulses, and management of flows after spawning lead to unsuccessful spawning, or death of recruits.	Possible	Moderate	Medium	Manage using expert knowledge on timing, magnitude, duration and rate of change for target fish species. Adaptively monitor during event, and after event.

Risk type	Description	Likelihood	Consequence	Risk level	Mitigation
Other considerations – unsuccessful bird breeding	Too short a duration of inundation of floodplain wetlands may result in a commencement of waterbird breeding and a subsequent abandoning of nests.	Possible	Moderate	Medium	Monitoring and adaptive management to maintain inundation should large scale waterbird breeding event commence.
Other considerations – drowning of floodplain vegetation	Floodplain inundation of too great a duration may result in the drowning of black box and potentially red gum trees.	Unlikely	Major	Medium	Ensure floodplain surfaces are not inundated for periods greater than 12 months.
Flooding of property	The duration of inundation of private property in the Edward-Wakool system may be lengthened when augmenting natural flood events in median and wet years.	Possible	Minor	Low	Work with other stakeholders to assess access risks in flood events and adjust watering accordingly.
Cutting off access	Some road access can be cut during flood events. Lengthening the duration of these events with Commonwealth water deliveries may lengthen the period for which certain roads cannot be used.	Possible	Minor	Low	Work with other stakeholders to assess access risks in flood events and adjust watering accordingly.
Infrastructure damage	Roads and other infrastructure may be damaged due to lengthened inundation from extension of flood events.	Unlikely	Minor	Low	Work with other stakeholders after watering events to assess any flood damage and adjust future watering accordingly.

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 River Murray, 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 increases in water availability, the water sharing plan will recommence from 1 July 2011.

The adaptive environmental water allocated under the water sharing plan is overseen by the NSW Office of Environment and Heritage (OEH). OEH is currently preparing an adaptive environmental water plan for the Murray Valley, which was available in draft form at the time of preparing this document (OEH 2010). During the 2009–2010 season, the Murray Lower Darling Environmental Water Advisory Group (MLD EWAG) was established to provide advice on the management of environmental water within the NSW Murray Valley. This includes representatives from the Murray CMA, and State Water and Australian Government observers.

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 Environmental Water allowance is listed in Section 8.1.3, Table 18 and is available for use across the NSW River Murray and Edward-Wakool areas. In addition to this, a Wakool System Allowance of 50,000–60,000 ML is provided as an additional volume by State Water to allow and account for delivery losses throughout the Wakool River, Yallakool Creek, Colligen Creek, Niemur River and Merran/Waddy Creeks. This allowance is not mentioned in the NSW Water Sharing Plan, however it has a long history of being implemented, and in 98 years in 100 is sufficient to provide minimum regulated flows through the Wakool system during the irrigation season.

Minimum flows are maintained along the Edward River and Gulpa Creek by River Murray Operations to maintain irrigation supply, stock and domestic supply, and to maintain water quality. This includes minimum flows during winter, listed in Table 16. In summer, operational flows are generally much higher than those specified in Table 16.

Table 16: Minimum Flow Maintained in the Edward River by River Murray Operations (MDBA 2010)

Location	Minimum Flow Maintained for Operations (ML/d)	Reason for Minimum Flow
Edward River offtake	100	for riparian and water quality requirements
Gulpa Creek offtake	80	for riparian and water quality requirements
Edward River at Stevens Weir	150	for riparian and water quality requirements
Edward River at Moulamein	250	to maintain access to stock and domestic supply offtakes

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. The volume of Commonwealth environmental water available in the Murray above the choke can be increased at any time by selling allocations tagged as sourced from elsewhere in the connected southern Murray-Darling Basin, and purchasing an equivalent volume in the Murray system upstream of the choke, subject to the trading rules described in Section 6.

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 River Murray 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.

Table 18: Environmental water currently held by other agencies in River Murray 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 ~15,000 ML high security and ~15,000 ML low security). 2,027 unit shares high security (~2,000 ML).	This plan is currently suspended but will recommence from July 1 2011.
Water Sharing Plan for the NSW Murray and Lower Darling Regulated Rivers Water Sources – **Murray Additional Environmental Allowance**	0.03 ML per unit share of high security (~6,000 ML).	This plan is currently suspended but will recommence from 1 July 2011.
Water Sharing Plan for the NSW Murray and Lower Darling Regulated Rivers Water Sources – **Barmah-Millewa Allowance Environmental Water Allocation (NSW)**	50,000 ML when NSW high security allocation is >=97% plus 25,000 ML when Victorian low reliability water share allocation is >30%.	This plan is currently suspended but will recommence from 1 July 2011. Account can be accrued over several years. The maximum credit that can be held against the allowance is 350 GL.
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%.	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.
River Murray – Flora and Fauna Conversion Further Amending Order (2009) – **The Living Murray**	40,298 ML low reliability water share. 3,630 ML high reliability water share.	
The Living Murray – **NSW Murray system**	1,887 ML 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 NSW OEH. 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 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 a reliability between the high and low security licences.

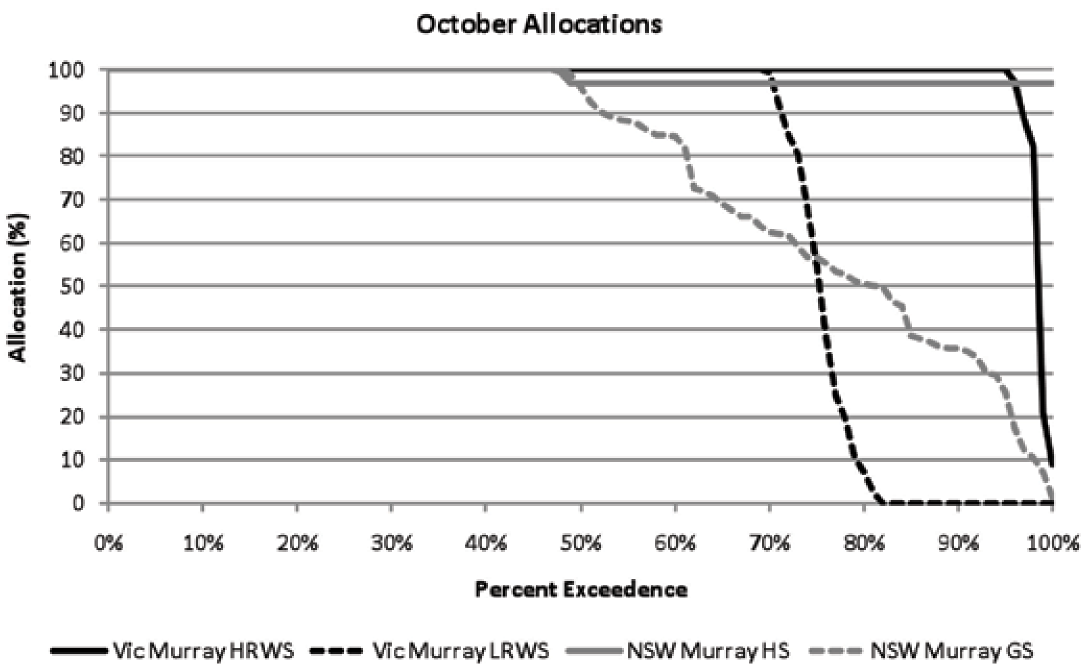

Figure 10: October seasonal allocations for the Murray system

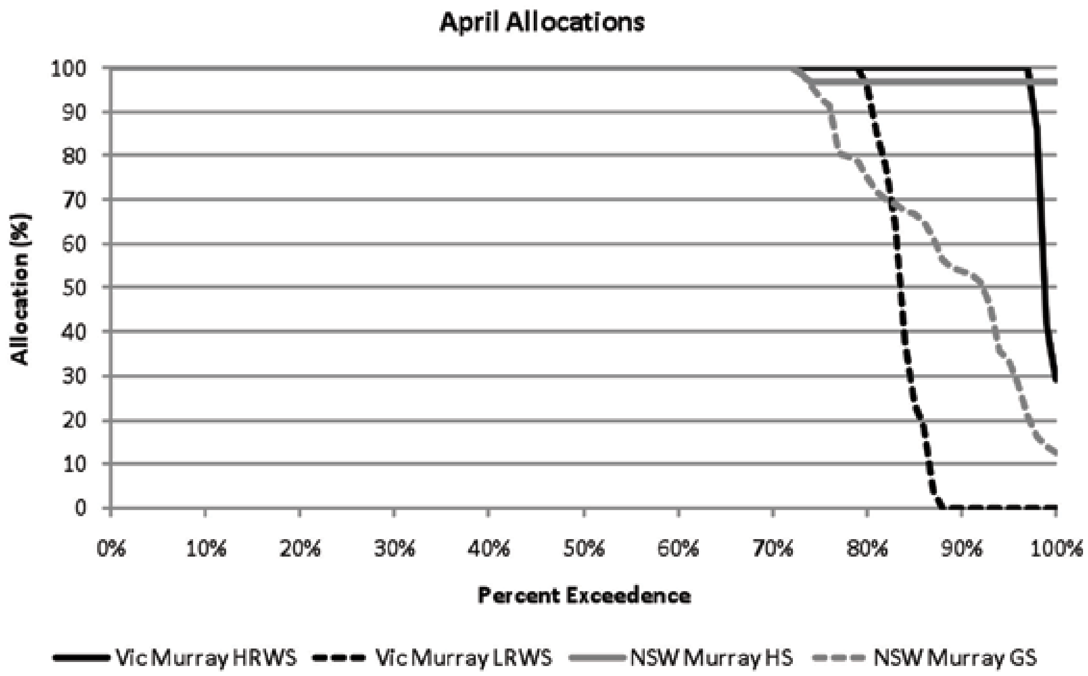

Figure 11: April seasonal allocations for the Murray system

The allocation expected to be available from Commonwealth environmental water holdings (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 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 allocations could result in approximately 5,000 ML of water being available for use 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 6.3.1.

Table 19: Likely announced allocation

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 (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

For the New South Wales Murray, in recent years the Office of Water has provided regular "critical water planning communiqués" 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 to give 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

There is limited routine monitoring undertaken in the Edward-Wakool system. There are various measuring points for environmental water. Key points are the regulators into Werai Forest, which are measured by field staff as required, and continuous flow monitoring points throughout the system. Instantaneous level, discharge, salinity (electrical conductivity) and temperature are recorded at a number of locations. A list of key sites is provided in Table 21. For a full list of sites and the parameters monitored at each site, refer to the NSW Water Information website http://waterinfo.nsw.gov.au/ and MDBA real-time data website at http://www.mdba.gov.au/water/live-river-data/yarrawonga-to-euston).

Table 21: Selected flow and water quality monitoring in the Edward-Wakool

Site number	Site name	Relevance to this plan
409003	Edward R at Deniliquin	Only gauged intermittently
409008	Edward R at offtake	Regulated inflows to Edward R
409013	Wakool R at Stoney Crossing	Outflows from Wakool R to River Murray
409014	Edward R at Moulamein	Outflows from Edward R to River Murray
407017	River Murray at Doctors Point	Indicates flooding of land on River Murray
409019	Wakool R offtake regulator	Wakool R offtake from Edward R
409020	Yallakool Ck at offtake	Yallakool Ck offtake from Edward R
409021	Wakool Main Canal	Offtake from Colligen Ck
409023	Edward R d/s of Stevens Weir	Indicator for Werai Forest inflows
409024	Colligen Ck below regulator	Colligen Ck d/s Wakool Canal
409025	River Murray d/s of Yarrawonga Weir	Triggers delivery of environmental water
409026	Mulwala Canal	Offtake from Yarrawonga Weir
409029	Mulwala Canal Escape	Outfalls to Edward R
409030	Gulpa Ck	Regulated inflows to Gulpa Ck
409036	Merran Ck u/s Wakool Junction	Outflows from Merran Ck to Wakool R
409044	Little Merran Ck at Franklings Bridge	Flow through Merran Cutting
409047	Edward R at Toonalook	Flow site u/s of Deniliquin
409056	Tuppal Ck at Aratula Rd	Flow site u/s of Deniliquin
409075	Bullatale Ck at u/s Edward R	Flow site u/s of Deniliquin
409086	Niemur R at Mallans School	Outflow from Niemur R to Wakool R
409098	Waddy Ck at d/s of regulator	Flow into Waddy Ck from River Murray

The Murray Region Algal Monitoring Program covers a small number of locations within the Edward-Wakool System, and monthly blue-green algal counts are conducted on the Edward River. Included in this program is less regular monitoring of dissolved oxygen, turbidity and pH (NSW Water Information).

In addition there are a number of one-off investigations and specific research activities. Recent investigations include:

- Industry and Investment NSW (I&I NSW) and Murray Catchment Management Authority joint project monitoring native fish response to flows.
- Assessment of acid sulphate soils in wetlands (Ward et al. 2010);
- Assessment of the causes and management of blackwater events in the system (Watkins et al. 2010; Baldwin 2009);
- Assessment of fish and drought refuges in the Wakool system (Gilligan et al. 2009);
- Assessment of fish populations and movements (Murray CMA);
- Environmental monitoring (water quality, waterbirds and other fauna) associated with environmental water allocations to Werai forests (e.g. Webster 2010); and
- Blackwater monitoring of 2010 flood events (TLM).

9.2 Operational water delivery monitoring

State Water and OEH provide a log of actions in any watering event to provide environmental flows. Environmental water managers should request that State Water and OEH commence documentation of watering events as they occur and finalise documentation as soon as the watering event has been completed. The Department of Sustainability, Environment, Water, Populations and Communities' pro-forma for an operational monitoring report is contained in Appendix C. This information can provide input into future environmental water delivery, as well as any applications for return flow credits to the NSW State Government.

9.3 Key parameters for monitoring and evaluating ecosystem response

Recommended monitoring to inform management of environmental water in the Edward-Wakool system and inform on the success of the program is summarised in Table 22.

Table 22: Monitoring plan for environmental water use

Ecological target	Hypotheses	Flow component	Indicator(s)	Monitoring sites	Frequency	Linkages and responsibility
Maintain water quality within channels and pools. Reduce the frequency and magnitude of blackwater events.	Baseflows during late winter / early spring; through to summer will prevent accumulation of litter in channel and reduce blackwater events.	Base flow	Litterfall Dissolved oxygen (DO)	Waterholes and streams: Colligen Creek, Niemur and Wakool Rivers.	Litterfall prior to flooding dry channels, DO monthly during inundation.	Recommended by Watkins et al. (2010). Litter not currently included in any monitoring programs. DO measured by NSW Office of Water algal monitoring program.
Promote productivity to maintain food webs and ecosystem function for in-channel flora and fauna.	Baseflows during late winter / early spring, when weather is cooler, followed by spring pulses will promote productivity.	Baseflow, spring pulses	Phytoplankton, macroinvertebrates, fish abundance.	Wakool, Niemur and Edwards Rivers, Colligen Creek.	To coincide with spring pulses.	Not currently monitored. NSW Office of Water also manages the algal monitoring program that provides counts of blue-green algae. Would need to be established with relevant agencies (Murray CMA, NSW Office of Water, Environmental Water Manager).
Maintain connectivity between main channel and lower commence to fill billabongs and backwaters.	Baseflows provided between July and December will connect pools and wetlands.	Baseflow	Stream flow and height.	Wakool, Niemur and Edwards Rivers, Colligen Creek.	Continuous	NSW Office of Water manages current instantaneous level and discharge at a number of gauging stations in the system. This may not provide sufficient information on connectivity with billabongs and backwaters.
Provide fish passage, successful fish recruitment. Maintain connectivity through the forest (Tumudgery Creek and Reed Beds Creek from Edward River to Colligen-Neimur) between river channel and low lying wetlands for fish and other aquatic fauna.	Instigation of spring pulses will promote successful fish recruitment. Environmental water allocations will improve fish passage through the system.	Baseflow, spring pulses.	Radio-tracking of native fish, fish community composition and abundance,	Yallakool / Wakool River	To coincide with spring pulses.	DPI NSW and Murray CMA joint program is providing comprehensive monitoring and investigation of native fish spawning over the next three years.
Maintain inundation of low lying wetlands associated with the river channels to prevent exposure of acid sulphate soils.	Baseflows between July and December will maintain inundation of low lying wetlands and prevent formation of sulphuric acid.	Baseflow	pH, salinity	Boiling Downs Creek, Glen Esk-Rusty Waterhole and Wakool River Billabong, other potential sites in the Wakool, Colligen and Niemur systems.	Monthly	NSW Office of Water also manages the algal monitoring program that includes pH. NSW Office of Water manages current instantaneous salinity and temperature monitoring at a number of gauging stations in the system.

Ecological target	Hypotheses	Flow component	Indicator(s)	Monitoring sites	Frequency	Linkages and responsibility
Prevent low dissolved oxygen events in channel systems by instigating diluting flows prior to and during water entering channels from floodplain environments.	Presence of water in streams will dilute low dissolved oxygen / high organic carbon coming of the floodplains.	Baseflow, spring pulses.	Dissolved oxygen, dissolved organic carbon.	Wakool River, Colligen Creek, Edwards River.	To coincide with floodplain inundation.	Not specifically monitored. DO measured by NSW Office of Water algal monitoring program. Would need to be established with relevant agencies (Murray CMA, NSW Office of Water, Forests NSW, Environmental Water Manager).
Maintain extent and health of reed bed vegetation.	Regular (1 to 3 year frequency) inundation of Reed Bed Creek Wetlands will maintain extent and composition of aquatic macrophytes.	Spring pulses, Werai watering.	Extent and composition of aquatic vegetation.	Reed Bed Creek Wetlands.	To coincide with Werai inundation.	Not currently monitored, but identified as a requirement under the ECD for Central Murray Forests Ramsar site. May be included by NPWS monitoring.
Maintain health of 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.	Spring pulses, floodplain watering.	Extent and canopy condition of floodplain forests.	Werai, Niemur Forests.	3–6 months post floodplain inundation.	TLM measures for icon sites, but not in Werai. May be included by NPWS monitoring.
Maintain the health of Black Box woodlands.	Regular (5 to 8 year frequency) inundation of river black box woodlands will maintain extent and maintain / improve condition.	Spring pulses, floodplain watering.	Extent and canopy condition of floodplain forests.	Werai, Lake Agnes.	3–6 months post floodplain inundation.	TLM measures for icon sites, but not in Werai. May be included by NPWS monitoring.
Promote successful breeding of waterbirds.	Inundation of wetlands for 3 to 4 months will instigate successful waterbird breeding.	Spring pulses, Floodplain watering.	Nest counts, recruitment.	Werai, Niemur Forests.	To coincide with wetland / floodplain inundation.	Not currently monitored, but identified as a requirement under the ECD for Central Murray Forests Ramsar site. May be included by NPWS monitoring.
Maintain health of ephemeral wetlands and watercourses.	Periodic inundation of ephemeral wetlands and watercourses will maintain / improve biodiversity.	Moderate to large watering events.	Community composition and abundance: macroinvertebrates, fish, aquatic vegetation.	Cockran Creek, Yarrien Creek; and Poon Boon Lakes.	To coincide with watering events.	Not currently monitored. Would need to be established with relevant agencies (Murray CMA, NSW Office of Water, Environmental Water Manager).

10. Opportunities

Some effluent creeks have been disconnected from the River Murray to protect Tocumwal and surrounding agricultural land from flooding. Better connectivity between the Edward River and the River Murray could be required to more efficiently deliver environmental flows; however this would require significant investigation and on-ground works. Options to improve connectivity between the River Murray and Tuppal Creek are being investigated by Murray CMA (2010) and include constructing a flow regulator through the levee bank and purchasing downstream flood easements.

The use of Millewa Forest regulators to deliver water to the Edward-Wakool system is considered feasible when undertaken in conjunction with a 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 River Murray volumes needed to increase flows in the Edward River.

Werai Forest is a throughflow wetland on a broad floodplain. There are currently no feasible opportunities to introduce structures to the forest to reduce watering requirements.

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. This could include any changes in the operation of the MIL Escapes.

The accounting rules for the Edward-Wakool system attribute forfeited water to NSW rather than being shared between States, as they are in the River Murray. Alternative methods of accounting for system forfeit in the Edward-Wakool could allow for more flexibility in the delivery of baseflows throughout the system, and requires further investigation.

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Appendix A: Significant flora and fauna

Significant species in the Edward-Wakool system (Herring et al. 2006; MDBA 2010a).

Common Name	Scientific Name	EPBC Status	TSA Status	Presence
Eastern great egret	*Ardea modesta*	Marine, Migratory		Known
Cattle egret	*Ardea ibis*	Marine, Migratory		Known
White-bellied sea eagle	*Haliaeetus leucogaster*	Marine, Migratory		Known
Forked-tailed swift	*Apus pacificus*	Migratory	Endangered	May
Latham's snipe	*Gallinago hardwickii*	Migratory	Vulnerable	May
White-throated needletail	*Hirundapus caudacutus*	Migratory	Vulnerable	Known
Australian painted snipe	*Rostralula australis*	Endangered	Vulnerable	May
Australasian bittern	*Botaurus poiciloptilus*	(Endangered IUCN Red List)	Endangered	Known
Regent Honeyeater	*Xanthomyza phrygia*	Endangered	Endangered	May
Swift Parrot	*Lathamus discolor*	Endangered	Vulnerable	Likely
Malleefowl	*Leipoa occelata*	Endangered	Vulnerable	Likely
Bush Stone-curlew	*Burhinus grallarius*		Endangered	Known
Superb Parrot	*Polytelis swainsonii*	Vulnerable	Endangered	Known
Magpie goose	*Anseranas semipalmata*		Vulnerable	Known
Freckled duck	*Stictonetta naevosa*		Vulnerable	Known
Blue-billed duck	*Oxyura australis*		Vulnerable	Known
Brolga	*Grus rubicunda*		Vulnerable	Known
Black-tailed godwit	*Limosa limosa*		Vulnerable	Known
Painted honeyeater	*Grantiella picta*		Vulnerable	Known
Black-chinned honeyeater	*Melithreptus gularis*		Vulnerable	Known
Hooded robin	*Melanodryas cucullata*		Vulnerable	Known
Grey-crowned babbler	*Pomatostomus temporalis temporalis*		Vulnerable	Known
Gilbert's whistler	*Pachycephala inornata*		Vulnerable	Known
Diamond firetail	*Stagonopleura guttata*		Vulnerable	Known
Murray cod	*Maccullochella peelii peelii*	Vulnerable	Vulnerable	Known

Common Name	Scientific Name	EPBC Status	TSA Status	Presence
Eel tailed catfish	*Tandanus tandanus*		Endangered population (MDB)	Likely
Murray hardyhead	*Craterocephalus fluviatilis*	Vulnerable	Vulnerable	May
Silver perch	*Bidyanus bidyanus*		Vulnerable	Known
Trout cod	*Maccullochella macquariensis*	Endangered		Known
Southern bell frog	*Litoria raniformis*	Vulnerable		Known
Spotted-tailed quoll	*Dasyurus maculatus*	Endangered	Vulnerable	Likely
Large-footed myotis	*Myotis adversus*		Vulnerable	Likely
Eastern long-eared bat	*Nyctophilus timoriensis*	Vulnerable	Vulnerable	Likely
Squirrel glider	*Petaurus norfolcensis*		Vulnerable	Known
Little pied bat	*Chalinolobus picatus*		Vulnerable	Known

Appendix B: Mulwala Canal airspace

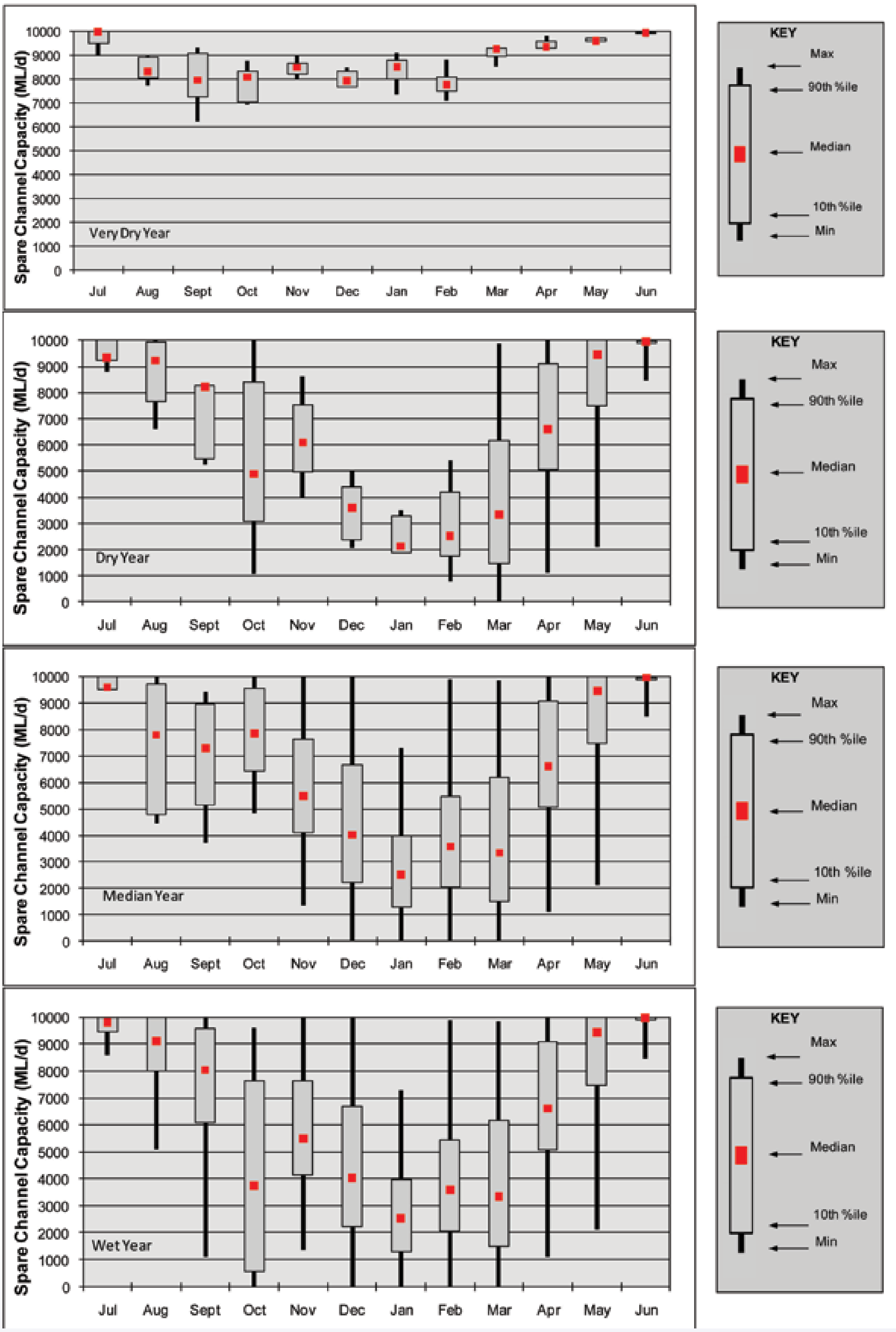

Figure 12: Spare channel capacity in Mulwala Canal, 1895–2009 (min, 10th percentile, median, 90th percentile and maximum daily values)

Appendix C: Operational Monitoring Report Template

Commonwealth Environmental Watering Program *Operational Monitoring Report* *Please provide the completed form to <insert name and email address>, Environmental Water Delivery Section, DEWHA 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	**<EWDS to prefill>**	**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) <EWDS to prefill>*	
	Total volume of water allocated for the watering event *CEWH:* *Other(please specify) :*	
	Total volume of water delivered in watering event *CEWH:* *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 D: Risk Assessment Framework

Table 23: Risk likelihood rating

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

Table 24: Risk consequence rating

	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

Table 25: Risk analysis matrix

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

Australian Government

Commonwealth Environmental Water

ENVIRONMENTAL WATER DELIVERY

Gunbower Forest

FEBRUARY 2012 V1.0

Image Credits

Flood waters in the forest – Gunbower Forest flood, September 2010
© MDBA, The Living Murray; Photographer David Kleinert

Gunbower Forest
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Cooling, MP and SKM (2012). *Environmental Water Delivery: Gunbower Forest*. Prepared by Ecological Associates and SKM for Commonwealth Environmental Water, Department of Sustainability, Environment, Water, Population and Communities, Canberra.

ISBN: 978-1-921733-33-8

DSEWPaC acknowledges the following individuals and organisations that have been consulted in the preparation of this document:

Melanie Tranter (North Central CMA)
Murray-Darling Basin Authority

Published by the Commonwealth Environmental Water Office for the Australian Government.

ENVIRONMENTAL WATER DELIVERY

Gunbower Forest

FEBRUARY 2012 V1.0

Environmental Water Delivery: Gunbower Forest

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

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

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

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

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

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

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

Commonwealth Environmental Water
Department of Sustainability, Environment, Water, Population and Communities
GPO Box 787, Canberra ACT 2601
Tel: +61 2 6275 9245

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Abbreviations

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

PART 1:
Management aims

1. Overview

1.1 Scope and purpose

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

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

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

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

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

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

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

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

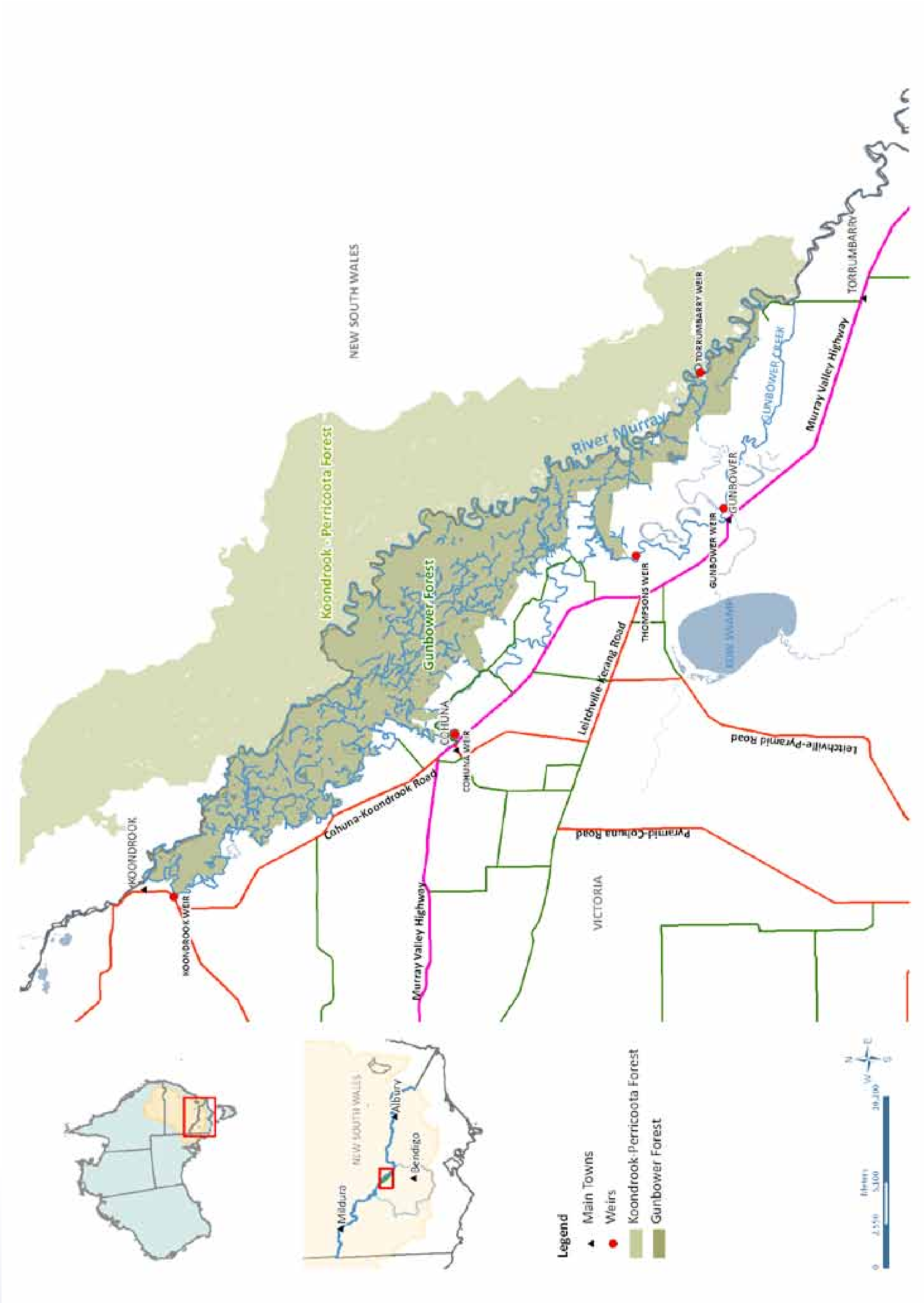


Figure 1: Gunbower Forest and Koondrook-Perricoota Forest (MDBA 2010a).

1.2 Catchment and river system overview

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

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

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

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

1.3 Overview of river operating environment

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

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

The principal sources of water for Gunbower Forest are:

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

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

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

1.4 Overview of forest operating environment

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

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

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

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

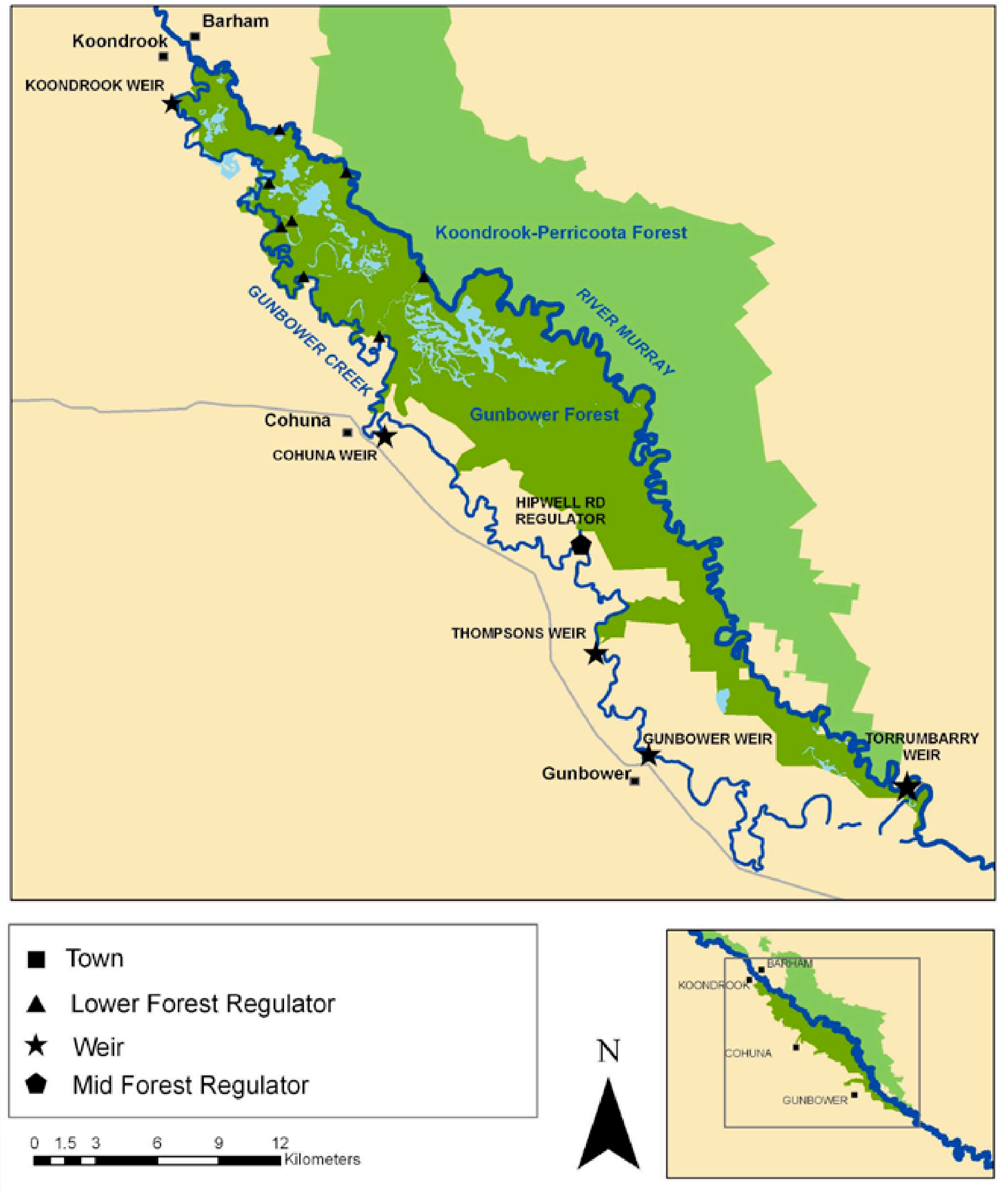


Figure 2: Water management overview.

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

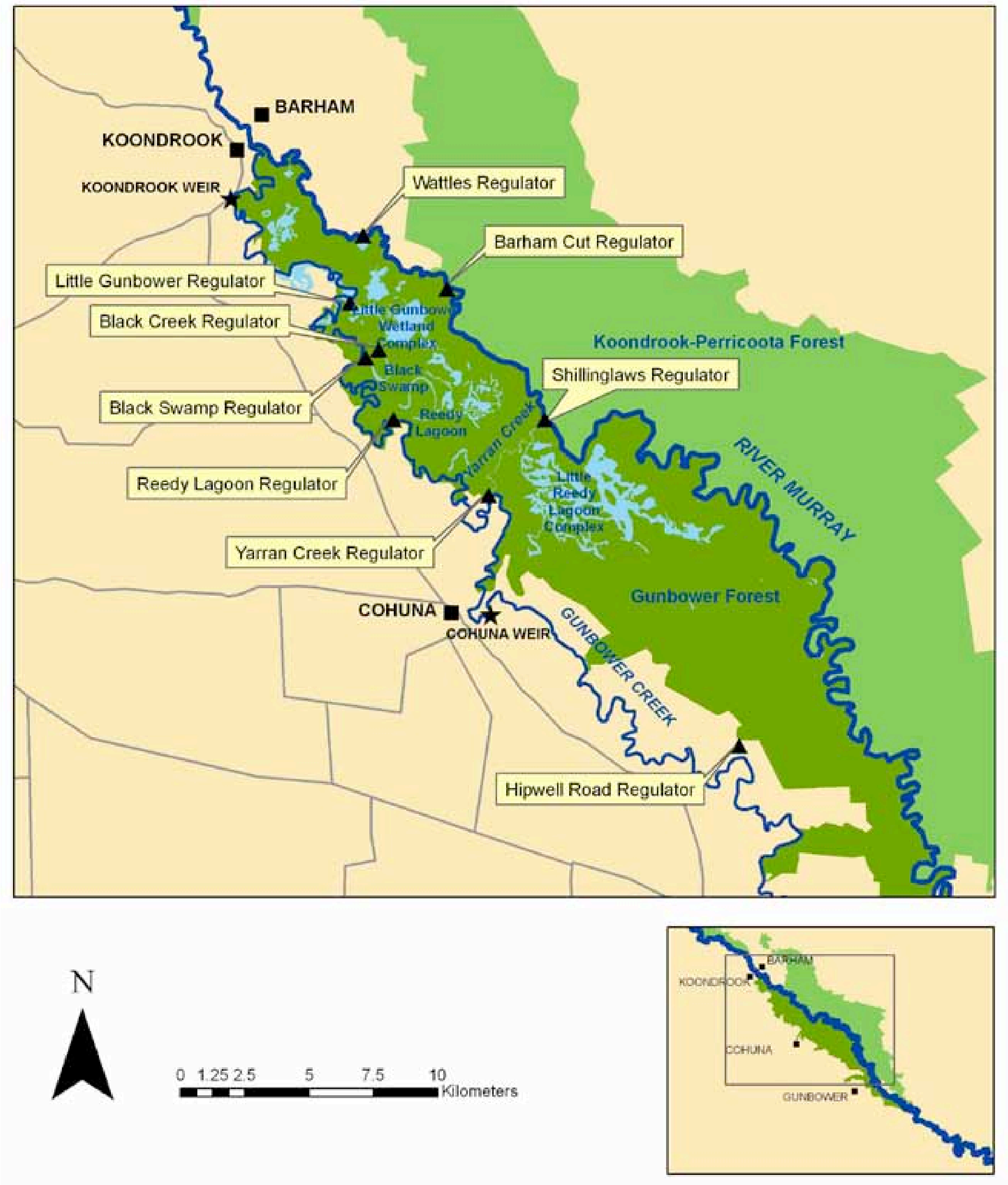


Figure 3: Lower landscape and Murray River effluent regulators.

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

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

Table 1: Forest regulator functions.

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

(Source: MDBA 2011)

2. Ecological values, processes and objectives

2.1 Ecological values

2.1.1 Overview of assets

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

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

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

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

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

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

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

2.1.2 Conservation value

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

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

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

Gunbower Forest includes the following vegetation communities of conservation significance:

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

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

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

2.1.3 Ecosystem structure

Forest and wetlands

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

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

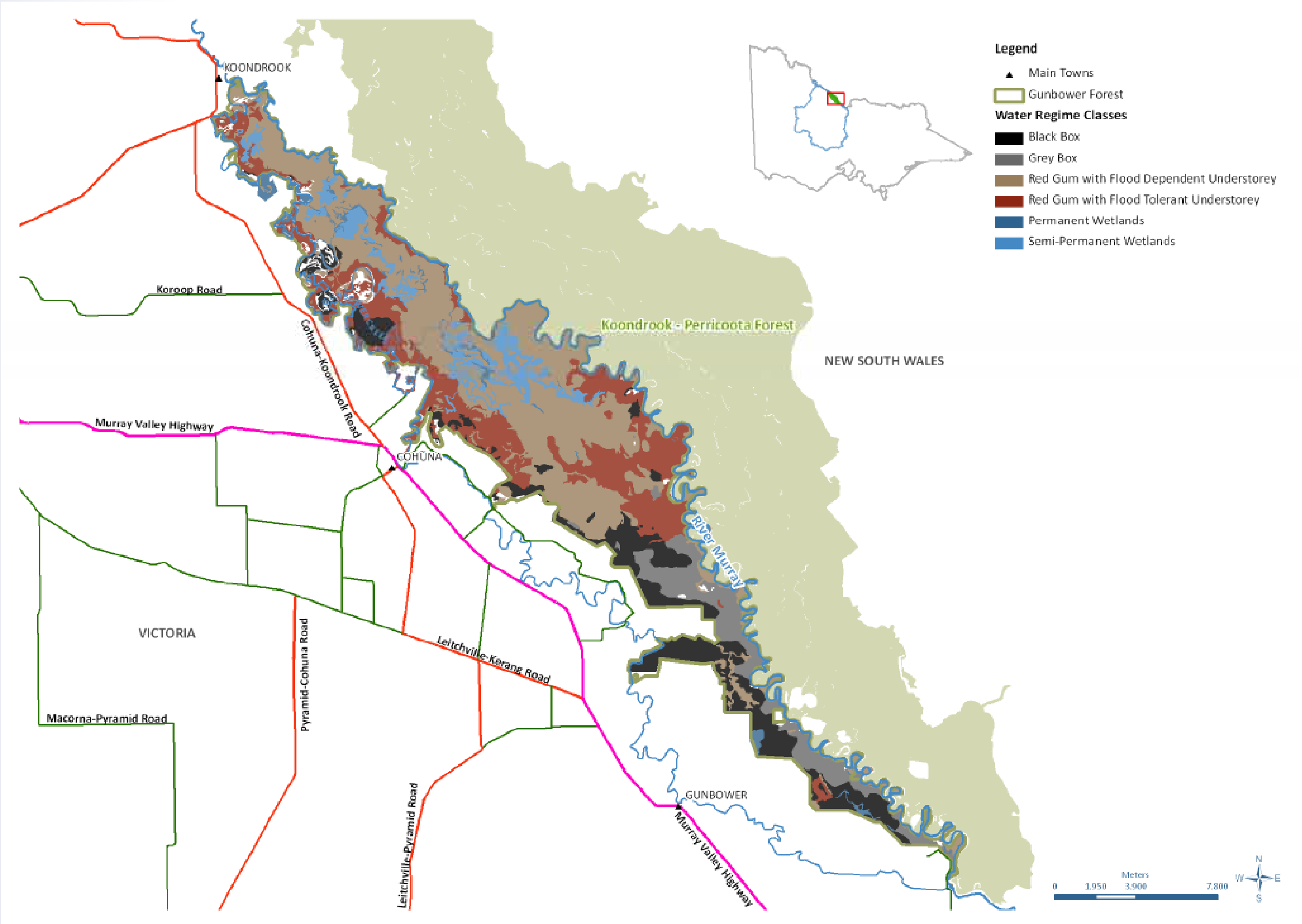


Figure 4: Water regime classes (MDBA 2010a).

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

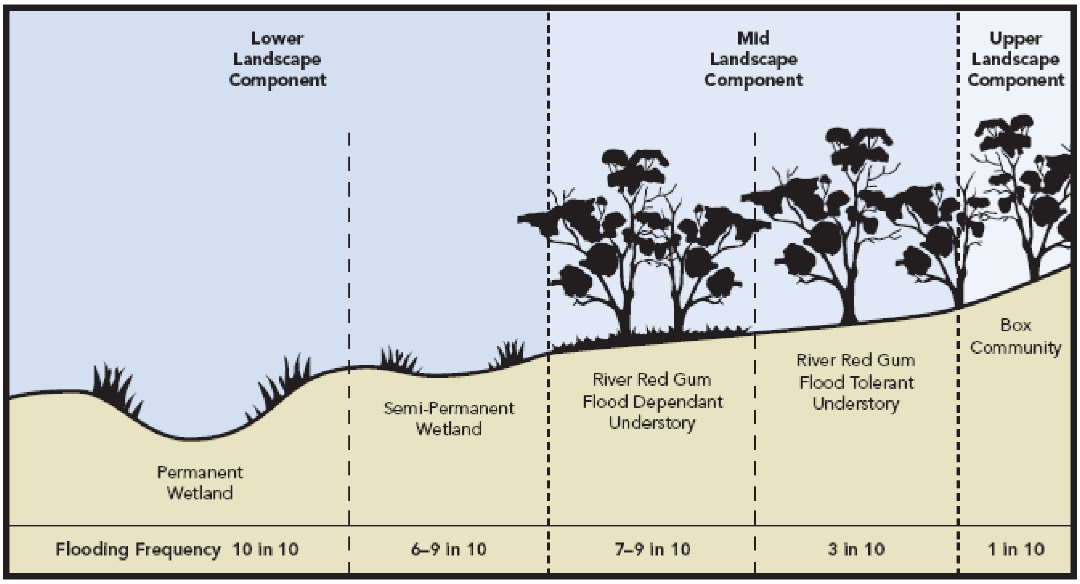


Figure 5: Schematic plan of water management areas in Gunbower Forest (MDBA 2010b).

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

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

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

Gunbower Creek

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

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

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

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

2.1.4 Current condition

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

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

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

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

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

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

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

Source: Ecological Associates (2003).

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

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

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

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

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

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

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

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

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

2.2 Ecological objectives

The objectives for watering options in Gunbower Forest are to:

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

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

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

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

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

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

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

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

Table 3: Ecological objectives for targeted water use

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

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

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

3. Watering objectives

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

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

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

Notes:

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

Source: Ecological Associates 2006

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

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

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

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

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

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

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

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

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

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

Extreme dry scenario

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

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

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

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

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

Dry scenario

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

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

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

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

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

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

Median scenario

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

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

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

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

Wet scenario

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

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

PART 2:
Water use strategy

4. Environmental water requirements

4.1 Baseline flow characteristics

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

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

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

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

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

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

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

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

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

4.2 Environmental water demands

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

5. Operating regimes

5.1 Introduction

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

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

5.2 Identifying water scenarios

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

Table 11: Identifying water scenarios

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

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

5.3 Delivery triggers and environmental watering options

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

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

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

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

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

5.4 Wetland regulators

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

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

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

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

Source: (MDBA, 2010b)

5.5 Channel capacity constraints

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

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

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

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

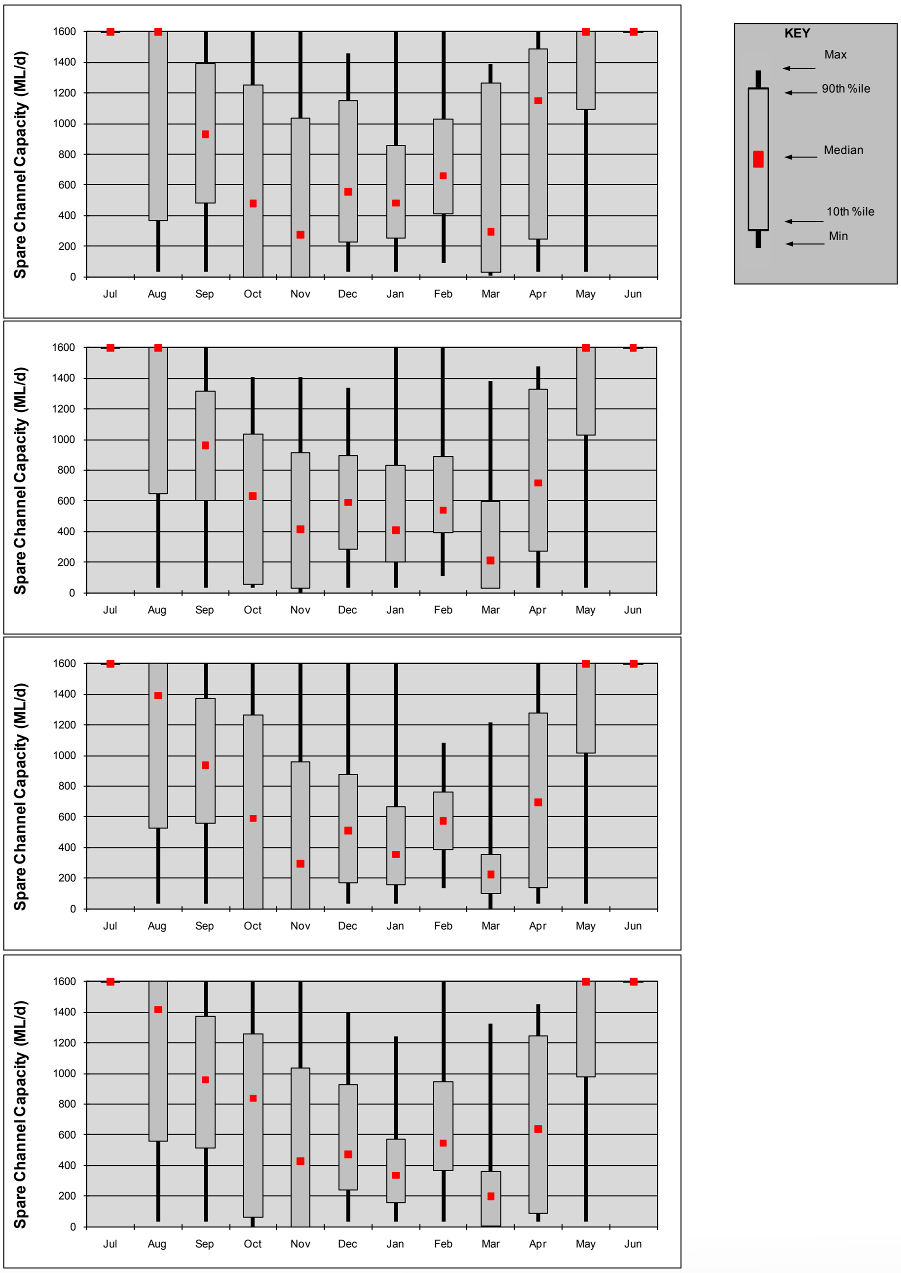


Figure 6: Spare channel capacity in Gunbower Creek upstream of the Hipwell Road Channel in (from top to bottom): very dry, dry, median and wet water scenarios.

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

5.6 Storage releases

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

5.7 Travel time

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

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

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

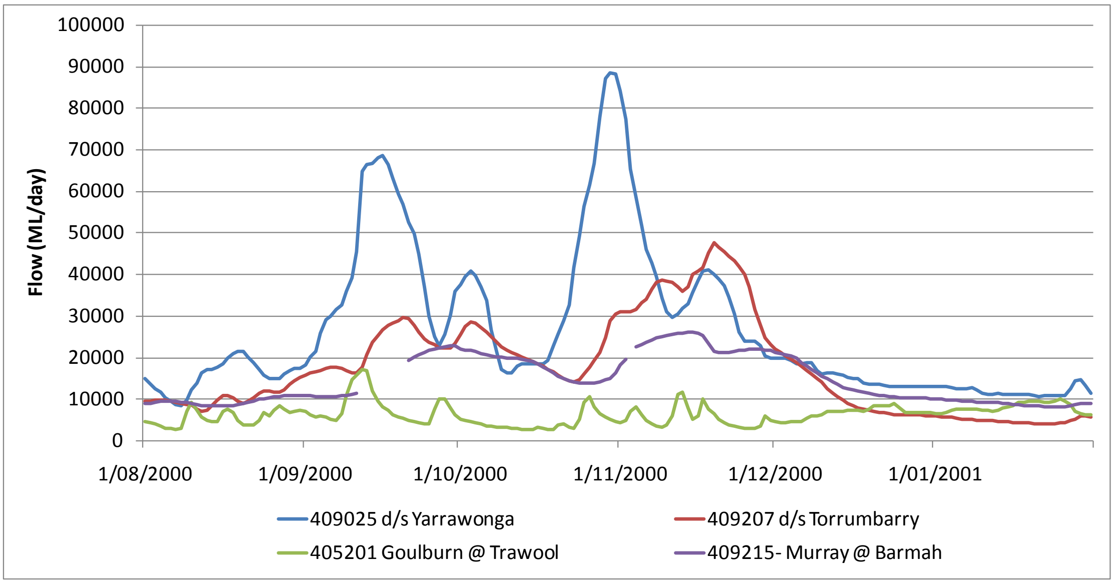


Figure 7: Murray River example event, spring 2000

5.8 Interactions with other assets

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

5.9 Recreational users

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

5.10 Water delivery costs

5.10.1 Delivery costs

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

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

5.10.2 Victorian carryover costs

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

6. Governance

6.1 Delivery partners, roles and responsibilities

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

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

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

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

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

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

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

Parks Victoria is the land manager for Gunbower National Park.

Koondrook-Perricoota management arrangements

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

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

6.2 Approvals, licenses, legal and administrative issues

6.2.1 Water shepherding and return flows

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

Table 15: Water use of different operational scenarios

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

Source: Water Technology, 2010

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

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

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

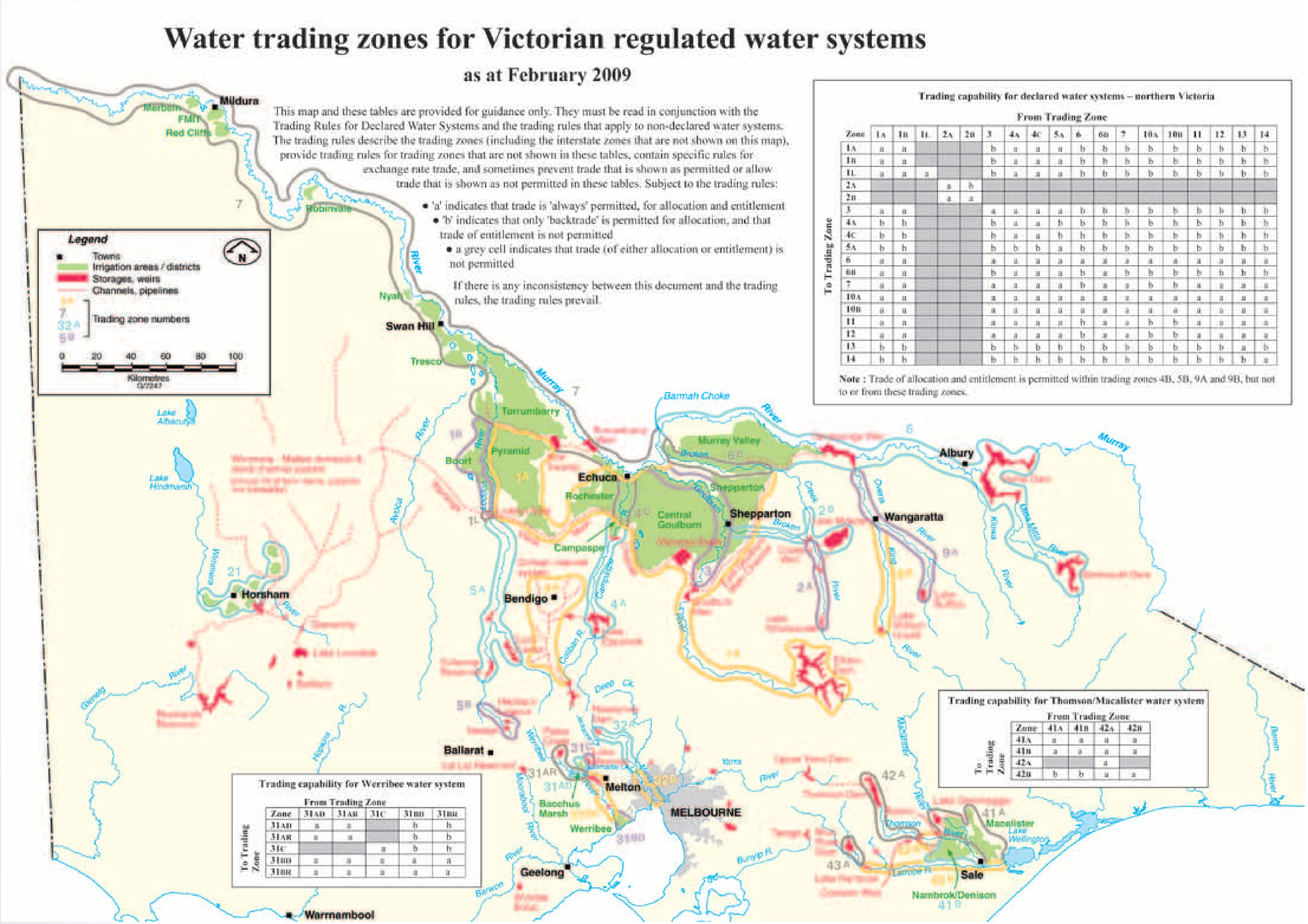
The assessment of the return flow calculations and crediting would be undertaken by Goulburn-Murray Water. Goulburn-Murray Water's assessment of credits would be subject to any rules set by the Victorian Minister for Water, as well as overall MDBA accounting arrangements and the availability of credits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

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

6.3 Trading rules and system accounting

6.3.1 Water trading

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



Trading capability for declared water systems – northern Victoria

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

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

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

Trading capability for Werribee water system

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

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

Trading capability for Thomson/Macalister water system

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

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

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

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

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

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

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

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

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

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

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

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

6.3.2 6.3.2 Water-storage accounting

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

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

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

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

7. Risk assessment and mitigation strategies

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

7.1 Blackwater events

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

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

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

7.2 Pest plants and animals

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

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

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

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

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

7.3 Fish breeding false starts

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

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

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

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

7.4 Interrupted waterbird breeding

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

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

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

7.5 Giant rush invasion of wetlands

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

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

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

7.6 River red gum encroachment in wetlands

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

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

This risk may be mitigated by:

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

7.7 Salinity

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

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

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

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

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

7.8 Acid sulfate soils

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

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

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

8. Environmental water reserves

8.1 Environmental water holdings and provisions

8.1.1 Water planning responsibilities

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

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

8.1.2 Environmental water provisions

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

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

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

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

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

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

8.1.3 Current water holdings

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

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

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

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

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

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

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

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

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

8.2 Seasonal allocations

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

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

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

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

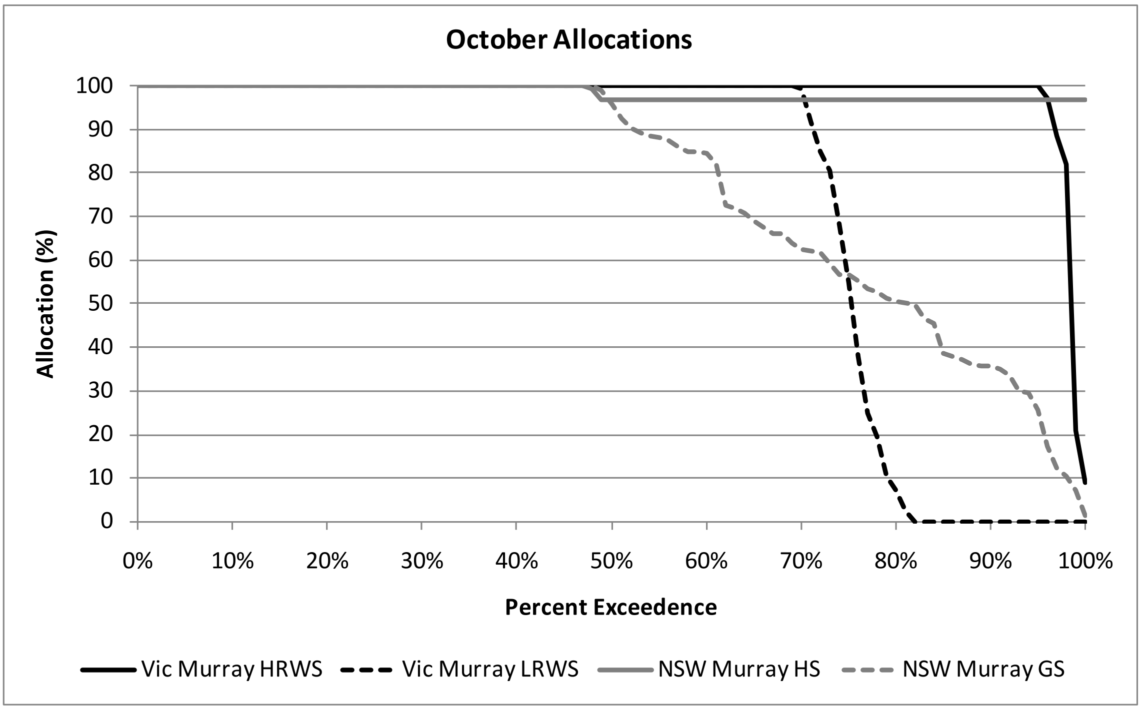


Figure 9: October seasonal allocations for the Murray system

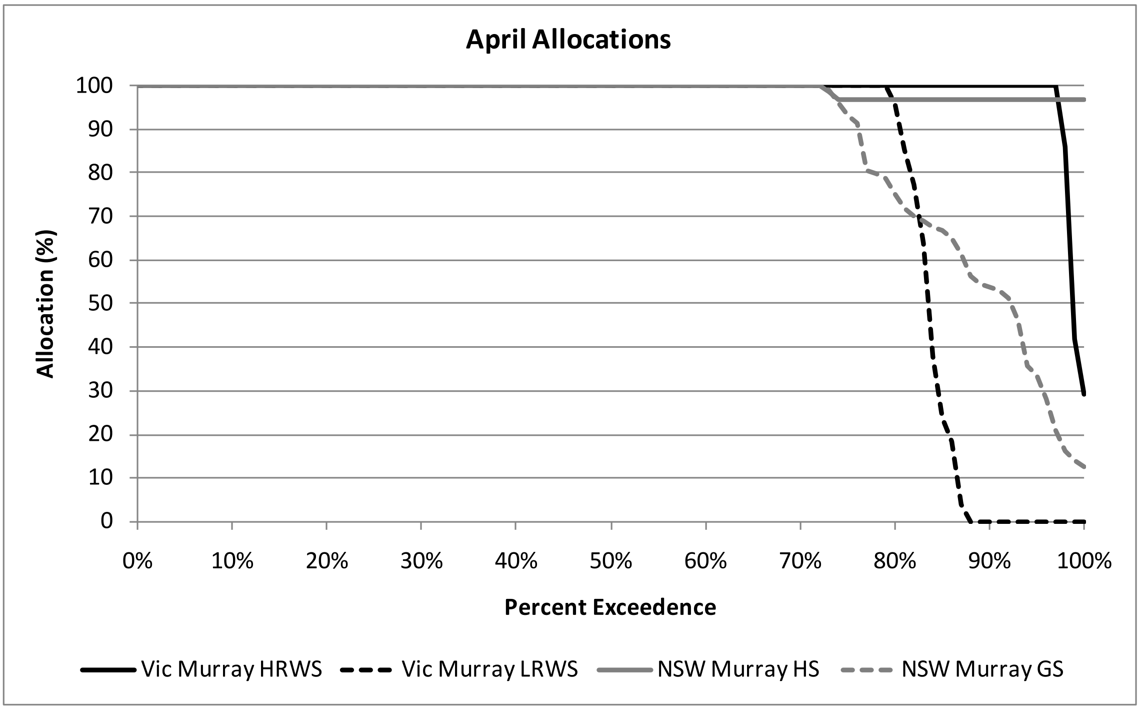


Figure 10: April seasonal allocations for the Murray system

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

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

Table 20: Likely allocation percentages

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

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

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

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

8.3 Water availability forecasts

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

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

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

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

PART 3:
Monitoring and future options

9. Monitoring evaluation and improvement

9.1 Existing monitoring programs and frameworks

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

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

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

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

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

9.2 Flow monitoring sites

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

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

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

9.3 Operational water delivery monitoring

Water delivery and water use

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

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

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

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

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

Table 24: Monitoring requirements for environmental water delivery and use

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

Watering Outcomes

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

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

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

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

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

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

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

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

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

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

Turtles are not monitored at Gunbower Forest.

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

Table 26: Monitoring requirements for ecological outcomes of environmental watering

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

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

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

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

10. Opportunities

10.1 Koondrook Weir fishway and passing flow

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

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

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

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

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

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

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

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

10.2 Lower landscape works

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

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

10.3 Upper Forest Channel

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

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

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

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

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

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

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

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

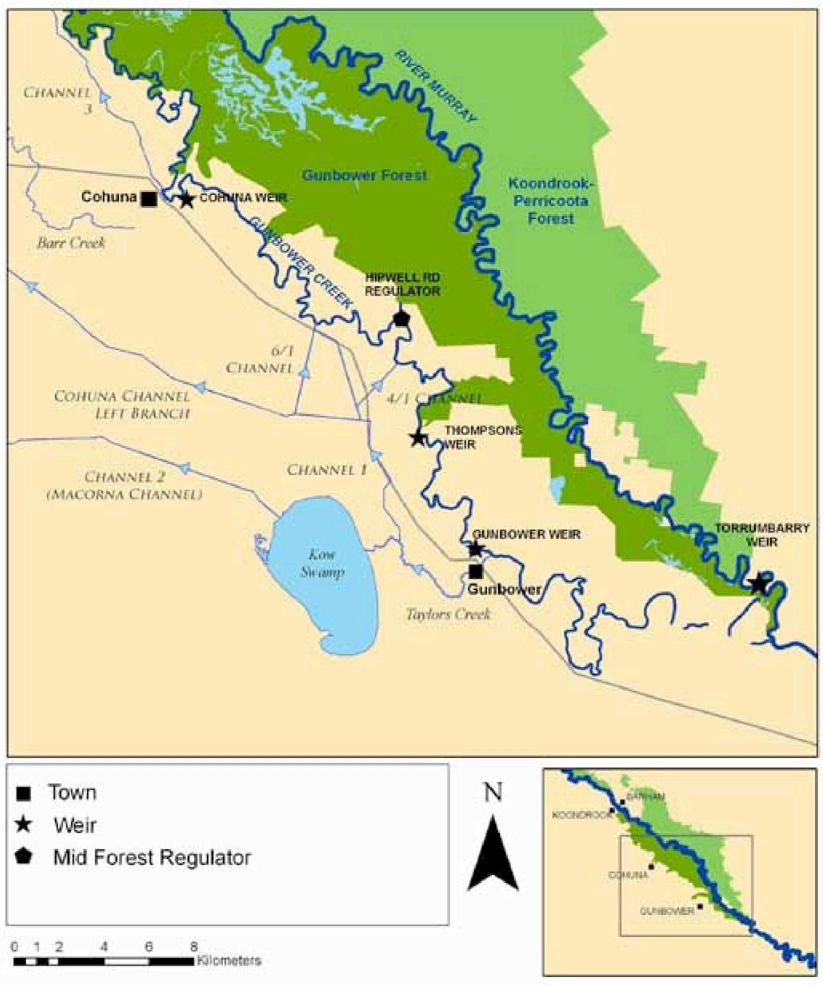


Figure 11: Elements of the Torrumbarry Irrigation Area in relation to the 6/1 Channel

10.5 National Channel fishway

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

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

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Appendix 1: Threatened flora and fauna

The presence of species has been ascertained through:

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

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

Threatened flora

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

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

Legend

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

Threatened fauna:

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

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

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

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

Legend

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

Appendix 2: Monthly streamflows at key locations

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

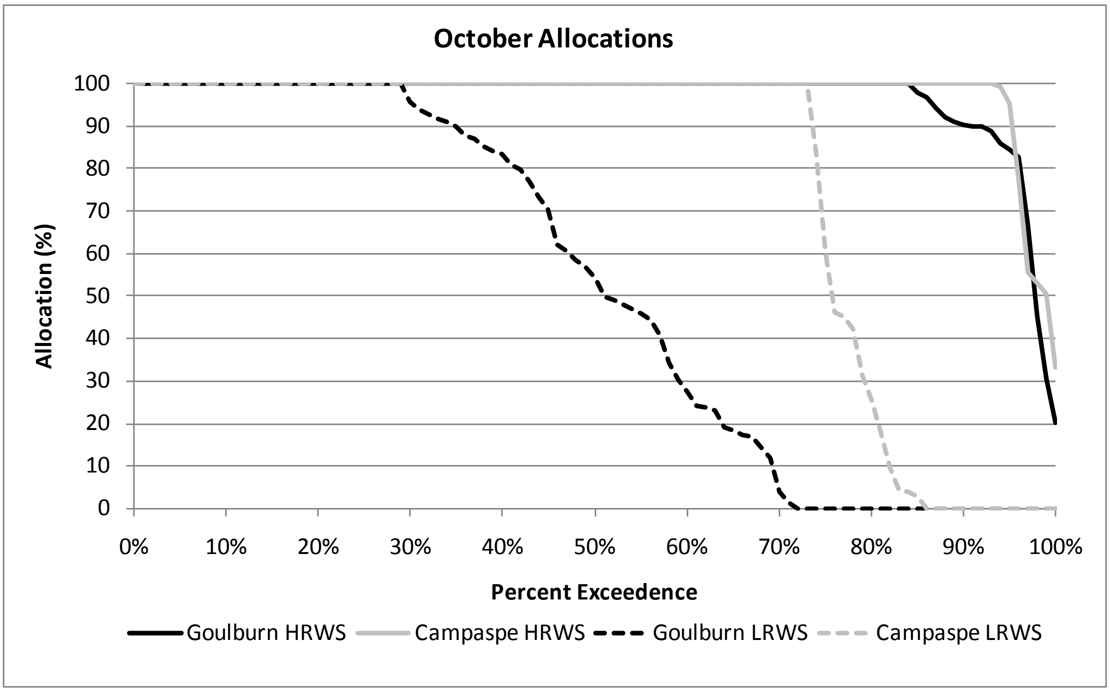
Average daily streamflows (ML/d) for the Murray River at Barham (1895–2009)

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

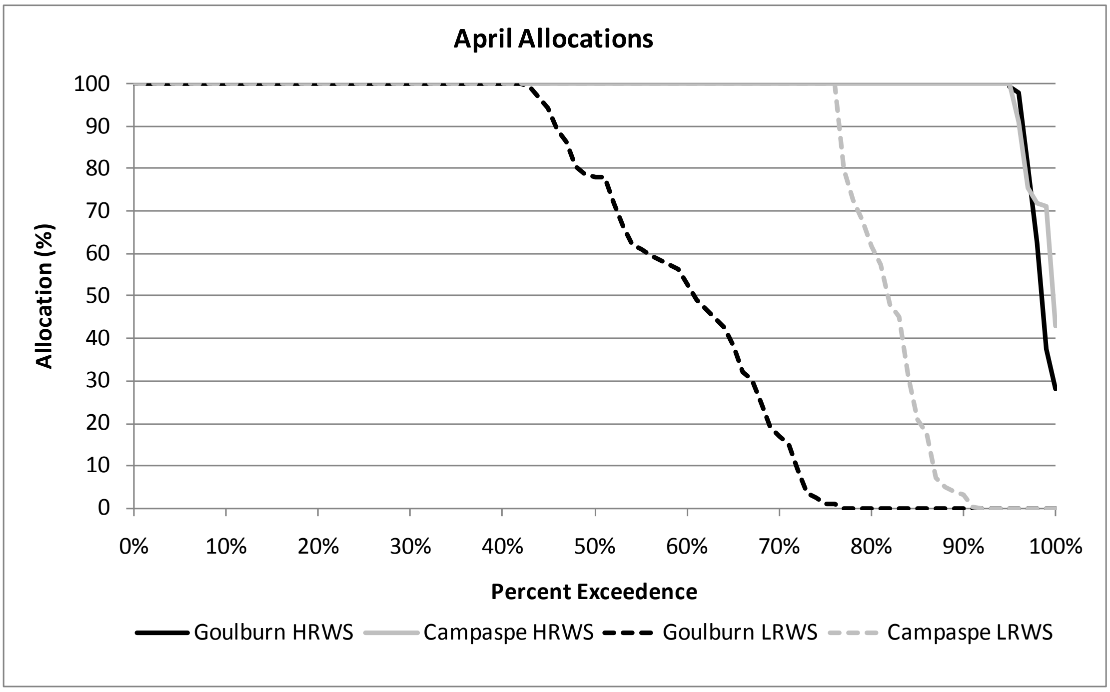
Average daily streamflows (ML/d) for the Murray River at Pental Island (1895–2009)

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

Appendix 3: Seasonal allocations



October seasonal allocations for the Goulburn and Campaspe systems.



April seasonal allocations for the Goulburn and Campaspe systems.

Appendix 4: Operational monitoring report template

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

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

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

Appendix 5: Risk assessment matrices

Risk likelihood rating

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

Risk consequence rating

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

Risk analysis matrix

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

Australian Government

Commonwealth Environmental Water

ENVIRONMENTAL WATER DELIVERY

Koondrook-Perricoota Forest

SEPTEMBER 2011 V1.0

Image Credits

Black Box Trees
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Red Gum Bark
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Hale, J and SKM (2011). Environmental Water Delivery: Koondrook-Perricoota Forest. Prepared for Commonwealth Environmental Water, Department of Sustainability, Environment, Water, Population and Communities.

ISBN: 978-1-921733-27-7

SEWPaC acknowledges the following individuals and organisations that have been consulted in the preparation of this document:

Murray-Darling Basin Authority
Digby Jacobs (NSW Office of Water)
Linda Broekman (Forests NSW)
Garry Smith (DG Consulting)
Daren Barma (Barma Water Resources)
Ben Gawne (Murray-Darling Freshwater Research Centre)

Published by the Commonwealth Environmental Water Holder for the Australian Government.

ENVIRONMENTAL WATER DELIVERY

Koondrook-Perricoota Forest

SEPTEMBER 2011 V1.0

Environmental Water Delivery: Koondrook-Perricoota Forest

Increased volumes of environmental water are now becoming available and this will allow us to pursue a larger and broader program of environmental watering. It is particularly important therefore that we seek regular input and suggestions from the community as to how we can achieve the best possible approach. As part of our consultation process 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 Koondrook-Perricoota Forest.

The Koondrook-Perricoota Forest supports significant ecological values, in particular river red gum forest and woodlands. Potential water use options for the Koondrook-Perricoota Forest include: providing flows to support vegetation condition and extent; providing flows to inundate permanent and semi-permanent wetlands and a portion of the floodplain to enhance channel and wetland habitats; providing flows to support life cycle processes of water-dependent fauna such as waterbirds and fish; and providing flows to prevent build-up of organic matter on the floodplain.

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

The work has been undertaken by consultants on behalf of the Commonwealth Department of Sustainability, Environment, Water, Population and Communities. Previously prepared work has been drawn upon, and discussions have occurred with organisations such as the New South Wales Office of Environment and Heritage, New South Wales Office of Water, 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 .

Commonwealth Environmental Water
Department of Sustainability, Environment, Water, Population and Communities
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Contents

Figures

Tables

List of Acronyms

AEW	Adaptive Environmental Water
AWD	Available Water Determination
CEWH	Commonwealth Environmental Water Holder
CMA	Catchment Management Authority
COAG	Council of Australian Governments
DO	Dissolved Oxygen
DSE	Victorian Department of Sustainability and Environment
EWAs	Environmental Water Allowances
FNSW	Forests New South Wales
MDB	Murray-Darling Basin
MDBA	Murray-Darling Basin Authority
MEP	Monitoring Evaluation Plan
MIL	Murray Irrigation Limited
MLDRIN	Murray Lower Darling Rivers Indigenous Nations
MLD EWAG	Murray Lower Darling Environmental Water Advisory Group
Murray CMA	Murray Catchment Management Authority
MWWG	Murray Wetlands Working Group
NSW	New South Wales
NOW	NSW Office of Water
OEH	NSW Office of Environment and Heritage
RERP	Rivers Environmental Restoration Program
SEWPaC	Department of Sustainability, Environment, Water, Population and Communities
TLM	The Living Murray

PART 1:
Management Aims

1. Overview

1.1 Scope and purpose of the document

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

To maximise the system's benefit, three scales of watering objectives have been 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.

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

Assets and potential watering options have been identified for regions across the Basin. This work has been undertaken as 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 options have been developed for each asset to meet watering objectives under a range of volume scenarios. Use of environmental water will aim to maximise environmental outcomes at multiple assets, where possible. Water use options will provide an "event ready" basis for the allocation of environmental water. Options are expected to be integrated into a five-year water delivery program.

3. Processes and mechanisms required to operationalise environmental water delivery have been documented and include:
   - delivery arrangements and operating procedures
   - water delivery accounting methods (in consultation with operating authorities) 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 options for the delivery of water to the Koondrook-Perricoota Forest for environmental outcomes. It should be noted, however, that the Koondrook-Perricoota Forest is within the larger water planning area of the Central Murray Floodplain (Yarrawonga to the Wakool junction). The actions and activities proposed within this document must be considered in conjunction with adjoining asset plans for the Barmah-Millewa Forest, Gunbower Forest and the Edward-Wakool system, as well as delivery plans for hydrologically connected assets such as the Lower Goulburn floodplain, Broken Creek and the Campaspe River.

1.2 Catchment and river system overview (general)

Koondrook-Perricoota is within the Murray-Darling Basin (MDB) on the floodplain of the Murray River downstream of the Torrumbarry Weir between Moama and Barham on the NSW side of the border. The MDB covers over one million square kilometres and comprises 14 per cent of the continent. Agriculture is the dominant economic activity in the MDB with pastoral and dryland farming (sheep, cattle and grain crops) the dominant land use. Approximately 75 per cent of the nation's irrigation is within the MDB and it dominates the landscape in portions of the catchment.

Within the MDB, Koondrook-Perricoota is located in 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 Wakool 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 Hume Dam 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 Hume Dam, 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).

Koondrook-Perricoota Forest is part of the NSW Central Murray State Forests Ramsar site and is contiguous with Gunbower Forest, which is on the southern (Victorian) side of the Murray River. The Ramsar site also includes Werai Forest on the Edward River and Millewa Forest on the Murray River upstream (Figure 1). Koondrook-Perricoota Forest spans two local government areas (Murray Shire Council and Wakool Shire Council). The 34,500 hectare site is completely gazetted as State Forests comprising of Koondrook State Forest, Perricoota State Forest and Campbells Island State Forest, with the majority of the site (approximately 80 per cent) production forestry. However, there are areas within the State Forests that are zoned as special protection and harvesting exclusion areas which are managed for conservation and in which timber harvesting is not permitted (Harrington and Hale 2011).

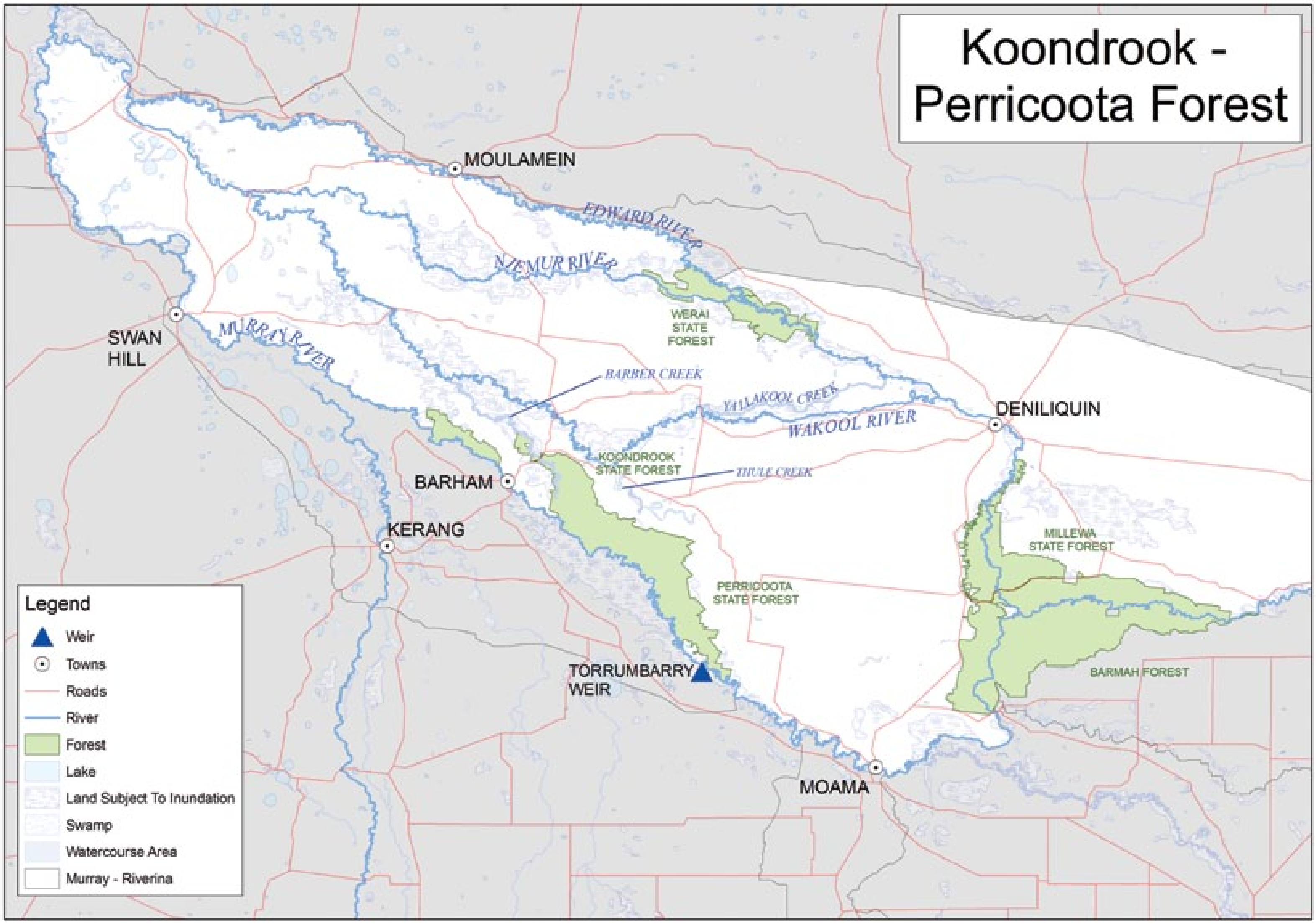


Figure 1: Location of the Koondrook-Perricoota Forest (SEWPaC 2011).

1.3 Overview of river operating environment

The principle sources of water for the Koondrook-Perricoota Forest are:

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

The major flow regulating structures on the Murray River system upstream of Koondrook-Perricoota Forest are Dartmouth Dam (3,856 GL), Hume Dam (3,005 GL), Yarrawonga Weir (118 GL), Lake Eildon (3,334 GL), Lake Eppalock (305 GL) and Torrumbarry Weir (37 GL).

Hume, Eildon and Eppalock Dams are managed primarily to capture inflows in winter and spring and release water as regulated flow to supply consumers. Irrigated agriculture is the largest consumer of water. Water for consumptive users is delivered via several main routes:

- Murray River flow below Hume Dam is diverted from Yarrawonga Weir to the north via Mulwala Canal (Murray Irrigation Limited) and to the south via Yarrawonga Main Channel (Murray Valley Irrigation Area). Hume Dam also supplies water down the Murray River, although deliveries are subject to the constraints of the Barmah Choke.
- Murray River flow is also diverted at Torrumbarry Weir (via National Channel to the Torrumbarry Irrigation Area), which is located directly upstream of Koondrook-Perricoota Forest.
- Goulburn River flow below Lake Eildon is diverted to the Waranga Basin and via the East Goulburn Main Channel at Goulburn Weir to the Shepparton and Greater Goulburn Irrigation Areas.
- Campaspe River flow into Lake Eppalock is diverted directly to Bendigo or released downstream for diversion by irrigators along the Campaspe River.

Koondrook-Perricoota Forest receives water from Murray River overbank flows downstream of Torrumbarry Weir. Works planned as a part of The Living Murray works plan will allow water to be diverted into Koondrook-Perricoota Forest from the Torrumbarry weir pool via new infrastructure (Torrumbarry Cutting) under regulated flow conditions.

The Koondrook-Perricoota Forest also includes Campbells Island State Forest which is located just downstream of the Koondrook-Perricoota Forest. Campbells Island State Forest receives water from the Murray River just downstream of Barham township via Little Murray River (which also supplies Merran Creek via the Merran Cutting).

2. Ecological values, processes and objectives

2.1 Ecological values

Koondrook-Perricoota Forest, together with Gunbower Forest on the southern bank of the Murray River, form the second largest river red gum (*Eucalyptus camaldulensis*) forest in south-eastern Australia (the largest being Barmah-Millewa). The site is listed as a wetland of international importance under the Ramsar convention and is one of three groups of forests that make up the NSW Central Murray State Forests Ramsar site. The NSW Central Murray State Forests site meets the following Ramsar criteria:

- 1 – representative and / or rare wetland types
- 2 – presence of threatened species
- 4 – supporting critical life-stages
- 5 – regularly supports > 20,000 waterbirds
- 8 – importance for native fish.

However, the majority of these are due mostly to the values of the Millewa Forest (which also form part of the Ramsar site) rather than Koondrook-Perricoota. Koondrook-Perricoota contributes to criteria:

- 1 – due to the river red gum forests and woodlands
- 2 – presence of the nationally threatened species swamp wallaby grass, Murray cod, and potentially supporting the Australasian bittern although the latter has been recorded infrequently.

It may also contribute to criterion 8 although the importance of Koondrook-Perricoota Forest for native fish has not been fully resolved (Harrington and Hale 2011).

The majority of the Koondrook-Perricoota Forest (82 per cent) is river red gum forest and woodland with smaller areas of black box (*Eucalyptus largiflorens*) woodland, grey box (*Eucalyptus microcarpa*) and terrestrial vegetation communities, the latter of which are predominately in the southern part of the site (Figure 2). Wetlands cover a relatively small proportion of the site (less than 5 per cent), which includes Pollacks Swamp (disconnected from the major area of the forest) and a number of intermittent flood runners (Figure 2).

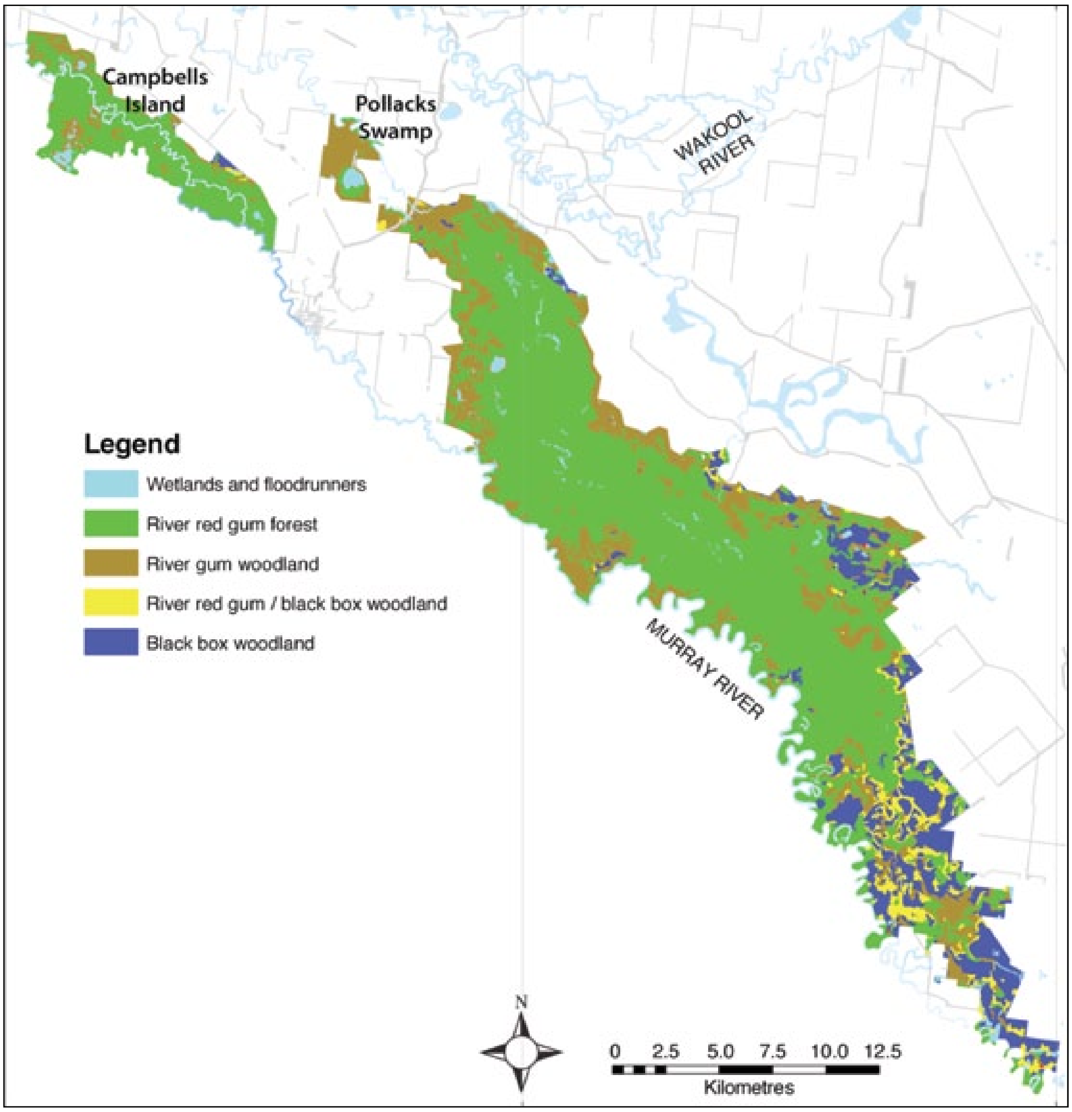


Figure 2: Vegetation and wetland habitats in the Koondrook-Perricoota Forest (Harrington and Hale 2011).

The system potentially supports over 40 significant flora and fauna species (see Appendix 1) as well as the "aquatic ecological community in the natural drainage system of the Lower Murray River catchment", which is listed as an endangered ecological community in NSW under the *Fisheries Management Act 1994 (NSW)*. However, the number of aquatic ecosystem-dependent significant species that are known to occur within the site are far fewer (Harrington and Hale 2011). The site supports a significant area of the nationally threatened swamp wallaby grass (*Amphibromus fluitans*) with the species present around Pollacks Swamp and in the river red gum forest understorey.

The site is known to support nesting waterbirds when inundated, with hundreds of birds recorded during 2000–01, 2003–04, 2004–05 and 2005–06 (Harrington and Hale 2011). Large events comprising thousands of birds have not been seen in the forest since a large natural flood in the mid 1970s (MDBC 2007). As with other forested floodplain sites, it is thought that Koondrook-Perricoota Forest may provide important habitat for native fish species when flooded. However, there is no data specific to the site to confirm this.

The environmental values of Koondrook-Perricoota Forest have been (and continue to be) impacted by altered hydrological regimes. There has been a reduction in the frequency and duration of spring inundation within the site, which has led to a wide range of impacts to ecological values. This has been exacerbated by the prolonged drought between 2000 and 2010, with no wide scale inundation of the forest during this period, and in some areas of the forest even longer.

The temporal loss of inundated floodplain forest habitat has resulted in a decline in waterbird breeding and impacted native fish. There is evidence of a decline in tree health with only 5 per cent of the forest considered in 'good' condition in 2009 (Cunningham et al. 2009). In addition, the extended period of dry conditions led to an excessive build up of organic matter on the floodplain that upon re-wetting in spring 2010 resulted in blackwater events in receiving water bodies such as the Thule Creek, Barbers Creek and Wakool River (MDBC 2010).

2.2 Ecological objectives

Proposed ecological objectives for the Koondrook-Perricoota Forest have been developed to maintain (or improve) the condition of the key environmental attributes. These are provided in Table 1.

Table 1: Ecological objectives for targeted water use.

Broad objective	Location	Ecological Targets
To maintain and enhance channel and wetland habitats.	Intermittent flood runners, permanent wetlands (e.g. Swan Lagoon) intermittent wetlands (e.g. Pollack Swamp).	Provide connectivity between aquatic habitats for fish passage.
		Promote productivity to maintain food webs and ecosystem function for in-channel flora and fauna.
		Provide habitat for aquatic fauna (fish, turtles, frogs, invertebrates).
		Maintain extent and enhance condition of aquatic vegetation.
To restore floodplains.	River red gum forests and woodlands (28,500 ha).	Maintain extent and improve condition of river red gum forests and woodlands.
		Promote successful breeding of waterbirds.
		Provide fish passage and allow biota to complete flow-driven critical life cycle processes such as spawning, seed setting and dormant stages.
		Maintain extent of swamp wallaby grass.
		Prevent excessive build-up of organic matter on the floodplain surface to minimise impacts to receiving waters from low oxygen blackwater events.
	Black box woodland (5,000 ha).	Maintain the health of black box woodlands.
		Promote productivity to maintain food webs and ecosystem function for in-channel flora and fauna.
		Maintain connectivity between main channel and floodplain.
		Provide fish passage and allow biota to complete flow driven critical life cycle processes such as spawning, seed setting and dormant stages.

3. Watering objectives

Proposed watering objectives have been developed to provide a water regime sufficient to maintain the ecological values of the site and to meet the ecological objectives provided in Table 1. Wetland habitats and vegetation communities within the site are distributed according to geomorphology, which affects the frequency and duration of inundation (Figure 3). This illustrates the gradient from the most frequently flooded wetlands that occur at the lowest elevations through the majority of the site, which is river red gum forest at mid elevations, through to river red gum woodland and finally box woodlands at the highest elevations on the floodplain.

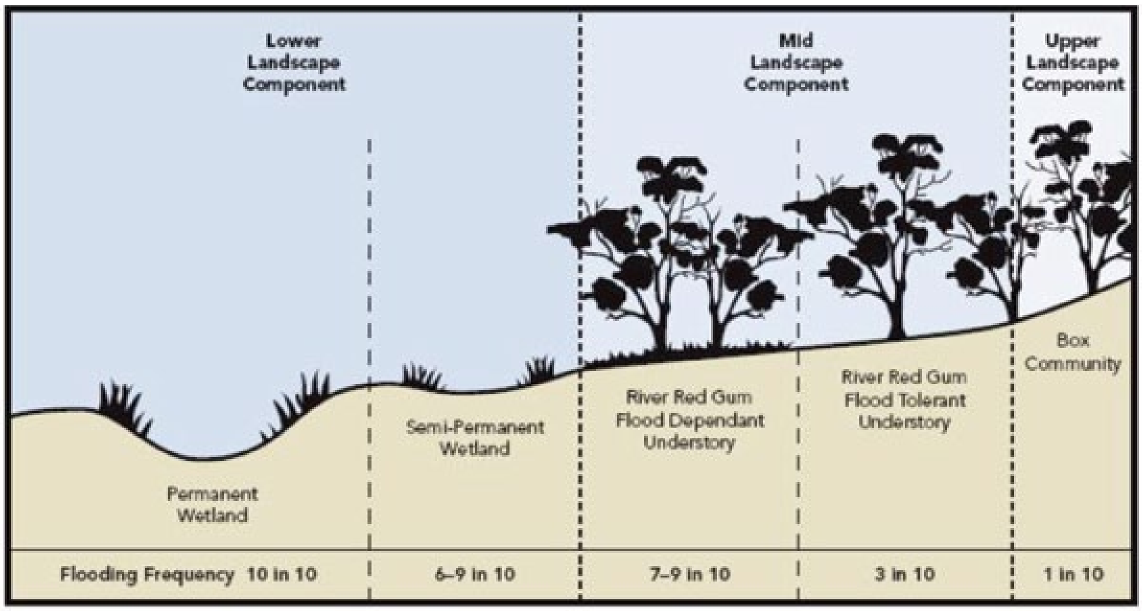


Figure 3: Vegetation associations, geomorphic setting and flood regime (MDBA in prep.).

Inundation of the floodplain produces a boom in productivity and is an important cue to initiate reproductive life cycle stages in wetland-dependent flora and fauna. Floodwaters must be of sufficient duration for species to complete life cycle stages such as nest building, egg laying and fledging of young in waterbirds, or flowering and seed set in aquatic flora. Temperature cues may also be important and as such the timing of inundation is also critical. Equally, appropriate floodwater recession is critical to avoid floodplain stranding of fish.

The water requirements upon which the watering objectives for the Koondrook-Perricoota Forest have been informed are summarised in Table 2.

Table 2: Water requirements for key ecological values in the Koondrook-Perricoota Forest (MDBA in prep.).

Ecological value	Inundation frequency	Duration of inundation	Timing of inundation	Maximum time between events
Permanent wetlands	80–100% of years	9–12 months	Year round	1 year
Intermittent wetlands and floodrunners	60–90% of years	2–8 months	Winter /spring	1 year
River red gum forest	30–90% of years	4 months (min.)	Winter /spring	5 years
River red gum woodland	10–40% of years	1–4 months	Winter /spring	7 years
Black box woodland	10–40% of years	1–4 months	Spring/summer	7 years
Waterbird breeding	Opportunistic	4–10 months	Spring/summer	6 years
Native fish	Opportunistic	4 months (min.)	Winter /spring	4 years

The water use management objectives provided in Table 3 have been developed on the assumption that the Koondrook-Perricoota Flood Enhancement Works, scheduled for completion in 2011 (though likely to be delayed by some months into 2012 due to wet conditions), are in place. This has a major impact on the volumes of water and river flows required to inundate areas of the forest. Campbells Island is outside the footprint of the Koondrook-Perricoota Flood Enhancement Works and thresholds for inundation of this 2,800 hectare forest could not be located when preparing this delivery document; but it is expected that it will be considerably higher than that for the remainder of the site once the flood enhancement works are in place. As such, this area is not considered further in this document, but is recognised as an area for further work.

Table 3: Proposed water use management objectives (all flows are quoted for the flow at the Koondrook-Perricoota Forest inlet regulator).

	Management objectives for specific water availability scenarios			
	Extreme dry Goal: Avoid damage to key ecological assets	**Dry** Goal: Ensure ecological capacity for recovery	**Median** Goal: Maintain ecological health and resilience	**Wet** Goal: Improve and extend healthy aquatic ecosystems
Water availability	Minimum allocation on record	30^{th} percentile year	50^{th} percentile year	70^{th} percentile year
	1,000 ML/d for 60 days (commencing June to November) to inundate permanent wetlands and flood runners. Maintain and enhance channel and wetland habitats: • Provide connectivity between aquatic habitats for fish passage. • Promote productivity to maintain food webs and ecosystem function for in-channel flora and fauna. • Provide habitat for aquatic fauna (fish, turtles, frogs, invertebrates). • Maintain extent and enhance condition of aquatic vegetation.	1,500 ML/d for 60 days (commencing June to November) to inundate permanent and semi-permanent wetlands, lagoons and floodrunners. Maintain and enhance channel and wetland habitats: • Provide connectivity between aquatic habitats for fish passage. • Promote productivity to maintain food webs and ecosystem function for in-channel flora and fauna. • Provide habitat for aquatic fauna (fish, turtles, frogs, invertebrates). • Maintain extent and enhance condition of aquatic vegetation.	2,000 ML/d for 90 days (commencing June to November) to inundate permanent and semi-permanent wetlands, and a portion of the floodplain (4,000 hectares). Maintain and enhance channel and wetland habitats: • All targets. Restore floodplain: • Maintain extent and improve condition of river red gum forests. • Promote successful breeding of waterbirds (short life cycle e.g. waterfowl). • Provide fish passage through existing fishways located at and inside the forest (more fishways may be constructed in the future). Also, to allow biota to complete flow-driven critical life cycle processes. These include spawning, seed setting and dormant stages that are completed during different phases of the wetting and drying cycle. • Maintain extent of swamp wallaby grass. • Prevent excessive build-up of organic matter on the floodplain surface to minimise impacts to receiving waters.	6,000 ML/d for 50 days (commencing June to November). Followed by 3,400 ML/d for 55 days. Manipulation of regulators to manage flood recession. Inundation of 17,800 hectares of floodplain forest. Maintain and enhance channel and wetland habitats: • All targets. Restore floodplains: • Maintain extent and improve condition of river red gum forests and woodlands. • Maintain the health of black box woodlands. • Promote successful breeding of waterbirds (long life cycle e.g. colonial nesters). • Provide fish passage through existing fishways located at and inside the forest (more fishways may be constructed in the future). Also, to allow biota to complete flow-driven critical life cycle processes. These include spawning, seed setting and dormant stages that are completed during different phases of the wetting and drying cycle. • Prevent excessive build-up of organic matter on the floodplain surface to minimise impacts of low oxygen blackwater events to receiving waters.

PART 2:
Water Use Strategy

4. Environmental water requirements

4.1 Baseline flow characteristics

The relationship between Murray River flow downstream of Torrumbarry Weir and overbank flows into the forest is shown in Table 4. A minimum flow of 15,000 ML/d is required for the commencement of flooding of low lying parts of the forest via the weir pool. A revised river-forest flow relationship for overbank flows has been provided and is included in the table below (FNSW pers. comm. 2011). These overbank flows are independent of the infrastructure works underway, as the works are designed to provide water to the forest under regulated conditions.

Table 4: Commence to flow for overbank flows into Koondrook-Perricoota Forest (FNSW 2009; FNSW pers. comm. 2011).

Murray River Flow (d/s Torrumbarry Weir) (ML/d)	Inflow to the forest via overbank flows (ML/d)
0	0
10,000	0
15,000	145
20,000	540
22,000	982
24,000	1,568
30,000	4,632
40,000	10,353
45,000	12,717
48,510	14,533
53,510	16,670
60,000	19,709

The area of inundation in the forest increases rapidly at Murray River flows downstream of Torrumbarry Weir greater than 30,000 ML/d, as shown in Figure 4.

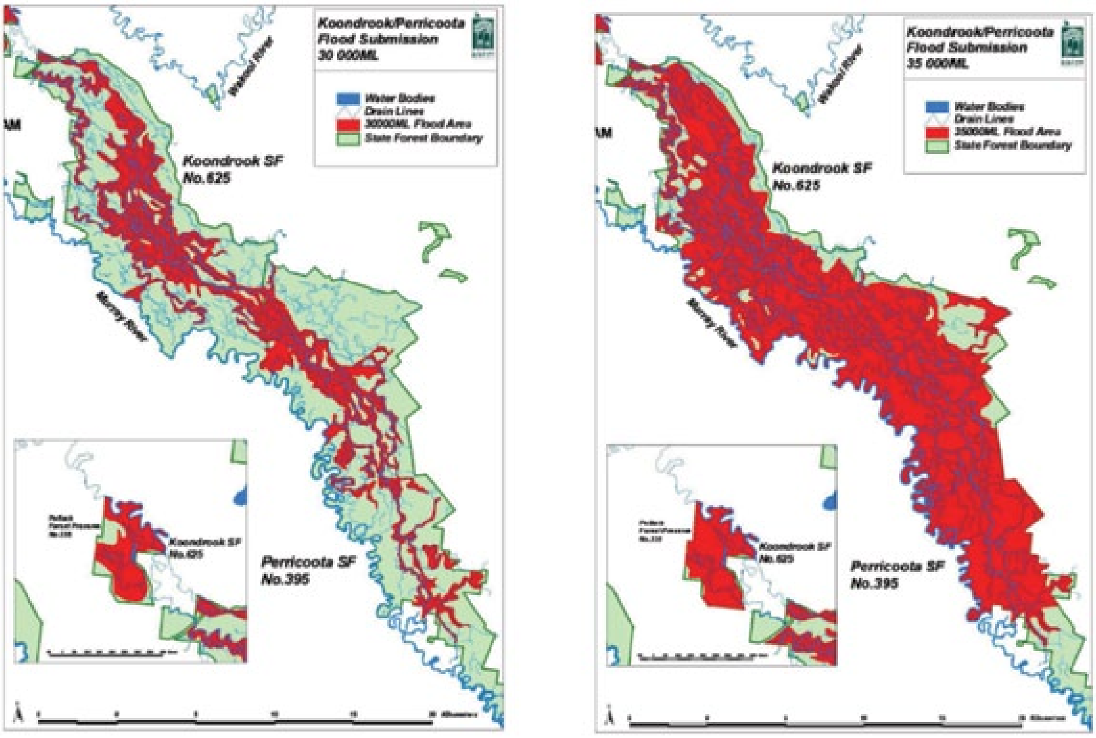


Figure 4: Koondrook-Perricoota Forest flood area at 30,000 and 35,000 ML/d downstream of Torrumbarry Weir (FNSW 2010).

Flows anticipated in each month under various climate conditions are presented for the Murray River downstream of Torrumbarry Weir in Table 5. Note that the values in Table 5 are derived independently for each month. Other sites of interest are presented in Appendix 3. This information is sourced from the MSM-Bigmod model of the Murray River system with The Living Murray deliveries in place (run #20507). This establishes the baseline conditions after the delivery of environmental flows under The Living Murray program (and prior to delivery of water by other environmental water managers) and is the scenario most representative of current conditions. Actual flows may be higher or lower than those presented below if the delivery of TLM water differs from that assumed in MSM-Bigmod. For example, if TLM water modelled as being delivered to ecological assets downstream of Torrumbarry Weir is instead diverted to sites upstream, then the baseline flows at downstream of Torrumbarry Weir would be lower than those shown in Table 5.

Table 5 shows that minimum flows downstream of Torrumbarry Weir are in the order of 1,500–2,500 ML/d (245 ML/d for August), whilst in a wet year, spring flows would be expected to exceed 25,000 ML/d, which is just below the flow threshold required for significant inundation at approximately 30,000 ML/d. Similar tables in Appendix 3 highlight that contributions from the mid-river tributaries (Broken Creek and Goulburn and Campaspe Rivers) are minimal in dry years. The tables in Appendix 3 also show that in wet years, spring flows (September to November inclusive) from the Murray River at Barmah are on average 65 per cent greater than inflows from the Goulburn River.

Table 5: Modelled streamflows (ML/d) for the Murray River downstream of Torrumbarry Weir (1895–2009) (Source: MSM-Bigmod run #20507).

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

With the construction of the Torrumbarry Cutting, up to 6,000 ML/d may be diverted into the forest when the Torrumbarry Weir pool is within plus or minus 0.05 metres of the full supply level (86.05 mAHD) (FNSW 2009). The Torrumbarry Cutting will enable water to be diverted into the forest without significantly raising Murray River water levels. In accordance with the Murray River system operating manual (MDBA 2010), since the construction of the new Torrumbarry Weir in 1996, the weir pool is generally maintained at the full supply level, as shown in Figure 5. Minor drawdown occurs for maintenance and the weir was drawn down and then surcharged during the 2010–11 floods. A level duration curve of historical weir pool data since the late 1990s, shown in Figure 6, indicates that the weir pool is above the desired minimum operating level for the Torrumbarry Cutting (86.0 mAHD) on around 85 per cent of days under current operation. This indicates that there are unlikely to be any significant constraints on the use of the Torrumbarry Cutting due to weir operation.

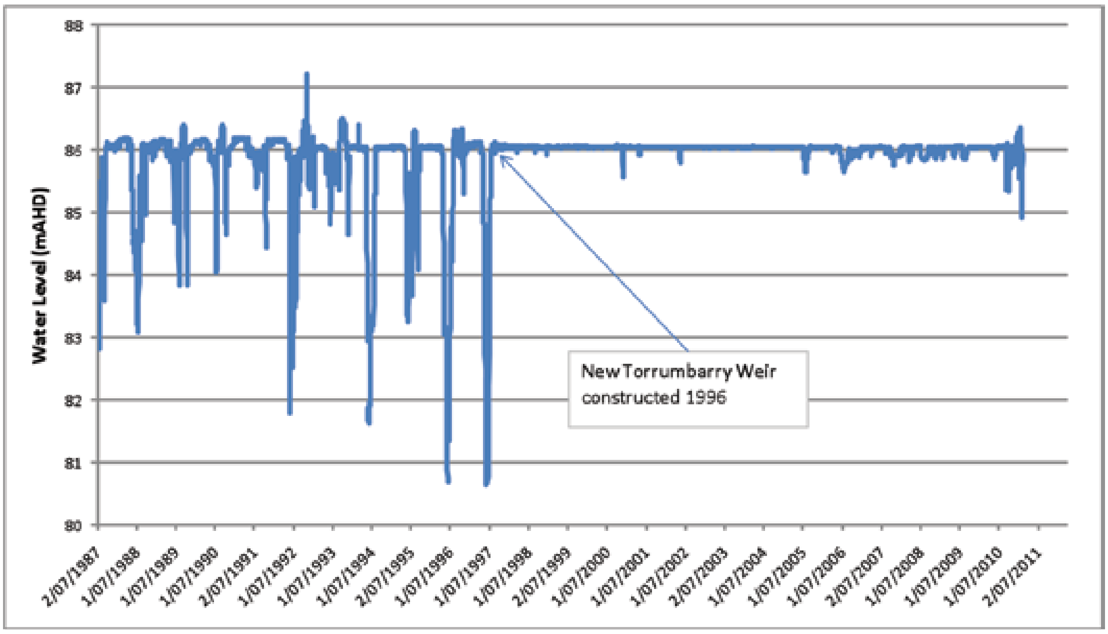


Figure 5: Historical Torrumbarry Weir Pool Level, 1987–2011.

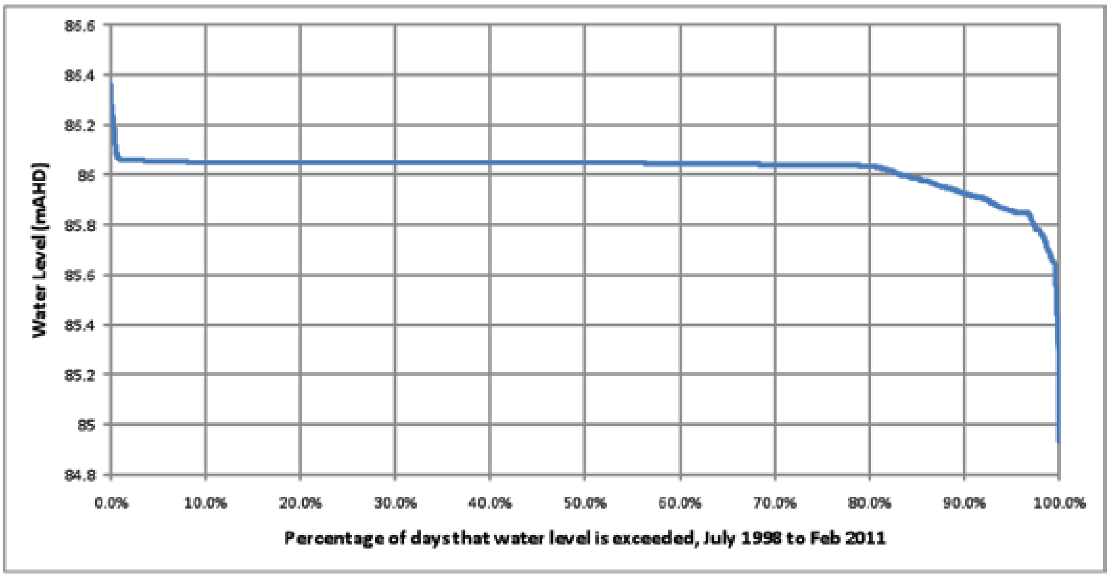


Figure 6: Historical Torrumbarry Weir Pool Level, 1998–2011.

Flow paths through the forest under natural flow conditions are illustrated in Figure 7. A description of the natural forest hydrology is provided in FNSW (2010), which describes that during overbank events the flow would naturally enter first via Swan Lagoon into the Burrumbury Creeks, which comprise several deep, well-defined channels. These channels then break down into a myriad of smaller, interlinked runners which eventually coalesce into several defined streams, the largest of which is Myloc Creek. Myloc Creek flows westward in conjunction with subsidiary runners, before becoming Barbers Creek. There are a number of secondary inflow points downstream of Swan Lagoon, although of much smaller scale. The most significant of these are Horseshoe Lagoon and Dead River, as well as the Black Gate, Penny Royal, Thule and Crooked Creeks. Outflow primarily occurs at Thule Creek, Barbers Creek, Calf Creek and Cow Creek into the Wakool River system. During large flood events water also drains out of Axe Creek and Pothole Creek.

Under regulated flow conditions water is delivered via a cutting which connects the Torrumbarry Weir pool with Bullock Head Creek. A diagram showing the location of the regulator on this cutting, and other regulators throughout the forest, is provided in Section 5 of this document. The flood enhancement works will increase measurement capabilities in the Koondrook-Perricoota Forest through the use of gauge boards and hydrographic stations along the regulators. The exact type and location of these measurement devices is still to be determined.

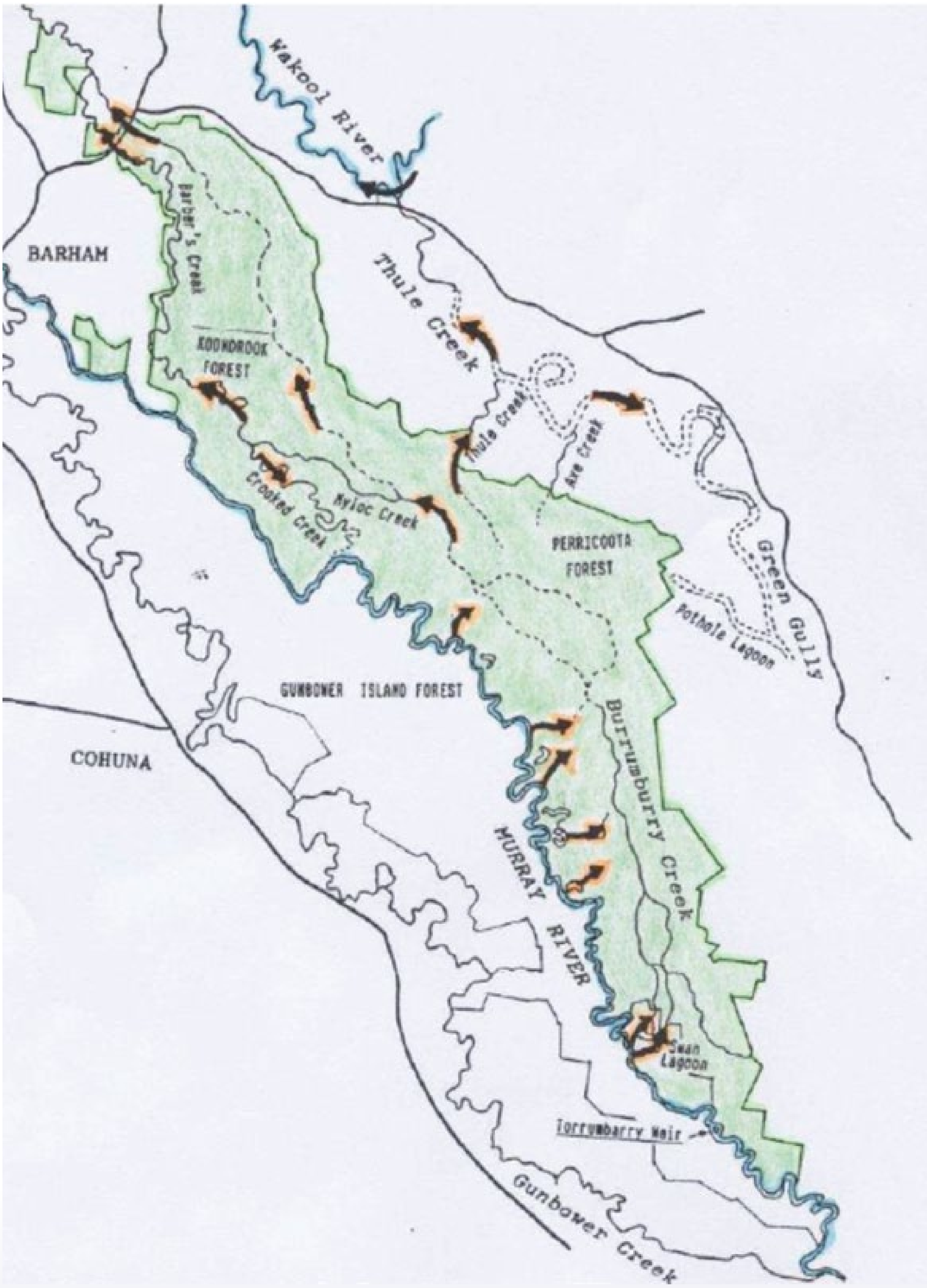


Figure 7: Natural flow paths through Koondrook-Perricoota Forest (FNSW 2010).

4.2 Environmental water demands

In Section 3 of this document flow targets were specified for different climate years. The flow targets (for inflow to the forest) for different climate years range from 1,000 ML/d for 60 days in a very dry year through to 6,000 ML/d for 50 days followed by 3,400 ML/d for 55 days in a wet year. The different flow targets may be supplied either via natural flooding (i.e. overbank flows in the river reach downstream of Torrumbarry Weir) or directly from the Torrumbarry Weir pool via the 'Torrumbarry Cutting' currently being constructed as a part of The Living Murray works program.

The frequency at which the flow targets are supplied from overbank flows or deliveries through the Torrumbarry Cutting was estimated using data extracted from the MSM-Bigmod model. The results of this analysis are shown Table 6. These results show that under current conditions with The Living Murray water deliveries already in place (run #20507), the wet year target flow magnitude would be met in 5.2 years out of every 10 years (all years). This figure is described as 'all years' because the event can occur within or outside of the wet climate year that it is designated as a target event for, for example it may occur in a median year instead, and so all data has been considered for all climate years. The model also found that in most instances the required event duration would not be supplied (the required duration would be met in 1.5 years out of every 10 years). If only wet years are considered, the wet year flow target is reached in 6.7 years out of every 10 wet years, but the specified duration is only reached in 2.5 wet years out of 10. Actual recurrence intervals may be higher or lower than those presented below if the delivery of TLM water differs from that assumed in MSM-Bigmod. For example, if TLM water modelled as being delivered to Koondrook-Perricoota Forest is instead diverted to other TLM sites, then the average recurrence interval of events would be lower than those shown below.

The median duration of events of naturally occurring overbank flows with TLM watering for the target wet year flow recommendation was only 43 days compared to a target of 105 days. This suggests that watering events are commencing, but are not being completed under the modelled TLM deliveries. The assumptions used in the TLM modelling and the driver for ceasing event delivery requires further investigation.

Table 6: Average recurrence interval for each flow target.

Climate Year	Event	Number of years in 10 with event of any duration (all years)	Number of years in 10 with an event of the specified duration (all years)	Number of years in 10 with event of any duration (climate years only)	Number of years in 10 with an event of the specified duration (climate years only)
Wet	6,000 ML/d for 50 days followed by 3,400 ML/d for 55 days	5.2	1.5	6.7 (in wet years only)	2.5 (in wet years only)
Median	2,000 ML/d for 90 days	6.1	1.6	5.7 (in median years only)	1.4 (in median years only)
Dry	1,500 ML/d for 60 days	6.1	3.1	5.6 (in dry years only)	2.2 (in dry years only)
Very dry	1,000 ML/d for 60 days	6.7	3.2	6.2 (in extreme dry years only)	0.6 (in extreme dry years only)

Under The Living Murray, the target watering regime is to deliver 6,000 ML/d for 50 days followed by 3,400 ML/d for 55 days (i.e. the wet year flow target) one in every three years. This means that significant volumes of water are already being delivered for the wet year event and environmental water managers only need to supplement these events by extending the duration when The Living Murray accounts are insufficient to complete the event for the full duration.

The estimated range of volumetric requirements is shown in Table 7 for each desired event. These volumes are in addition to any water delivered under The Living Murray program. The triggers for implementing each flow recommendation in this analysis are in line with the operational triggers outlined in Section 5. Hydrologic analysis for this delivery plan is based on static output from MSM-Bigmod, that is, feedback loops within the system have not been incorporated into the modelling. For example, return flows from watering the Barmah-Millewa Forest have not been incorporated and so the river flow values used for Koondrook-Perricoota Forest are not dynamically responsive to changes in water levels. If MSM-Bigmod was to be used interactively, that is, feedback loops be incorporated in the modelling, then an investigation into greater flexibility in delivery rules and improved understanding of the volumes required to be delivered may be possible.

The required delivery volume may vary considerably from year to year depending on the ability to forecast flow conditions prior to deciding whether to proceed with the event. The volume required, summarised in Table 7, is therefore indicative only. Actual volumes should be based, as best as possible, on MDBA operational model forecasts.

Table 7: Range of additional volumes required to achieve the desired environmental flow in given climate years.

Climate Year	Event	No. of years in 10 event is triggered in given climate years	Average volume provided in given climate years (GL/year)	Maximum volume provided (GL/year)	Average volume provided in all climate years (GL/year)
Wet	6,000 ML/d for 50 days followed by 3,400 ML/d for 55 days	3.9	32.8	393.9	10.3
Medium	2,000 ML/d for 90 days	8.1	100.1	180.0	18.5
Dry	1,500 ML/d for 60 days	7.8	63.6	90.0	12.8
Very dry	1,000 ML/d for 60 days	9.4	40.3	60.0	12.0
Total					**53.7**

Return flow volumes from the watering of Koondrook-Perricoota Forest can be significant and have been estimated at 70–84 per cent of delivered flows (FNSW et al. 2008). The figures in Table 7 do not include an allowance for return flows, which could substantially reduce the net volume required if those return flows can be re-credited to environmental water managers. Further discussion on return flows is provided in Section 6.

4.3 Summary of environmental water demands

The environmental water demands from the range of proposed events are shown in Table 8. This table indicates that the volume required to supply all of the proposed events averages 54,000 ML per year but could range from no requirement to over 390,000 ML per year in any given year. Demands for water are significantly greater in medium years than in dry to very dry years. This calculation was based on supplementing the existing flows, including current TLM deliveries. Actual shortfall volumes may be higher or lower than those presented below if the delivery of TLM water differs from that assumed in MSM-Bigmod. For example, if TLM water modelled as being delivered to Koondrook-Perricoota Forest is instead diverted to other TLM sites, then the additional volume required to achieve the target flows would be greater than those shown below.

Table 8: Range of additional volume to achieve the desired environmental flow across all climate years.

Climate Year	Minimum annual volume in given climate years (GL/year)	Maximum annual volume in given climate years (GL/year)	Average annual volume in given climate years (GL/year)	Average annual volume, averaged over all climate years (GL/year)
Wet	0.0	393.9	32.8	10.3
Medium	0.0	180.0	100.1	18.5
Dry	0.0	90.0	63.6	12.8
Very dry	0.0	60.0	40.3	12.0
All years				**53.7**

The effect of the proposed environmental flow recommendations on the average and maximum interval between events is shown in Table 9. This table shows, for example, that by utilising environmental water in the manner proposed, the target flow for the very dry year would be provided in almost all years and the frequency of occurrence of all events would be significantly increased. As stated previously, these results are based on hydrologic data from MSM-Bigmod which has The Living Murray deliveries already in place. The target duration for the wet year event is not reached (i.e. provided 5.6 years in 10 in wet years rather than in all wet years), because not all designated wet years have an overbank flow to initiate watering the forest.

Table 9: Change in recurrence intervals under proposed watering regime.

Climate year	Event	No. of years in 10 with event of specified duration (all years)		No. of years in 10 with event of specified duration (climate years only)	
		Current	Proposed	Current	Proposed
Wet	6,000 ML/d for 50 days followed by 3,400 ML/d for 55 days	1.5	1.8	2.5	5.6
Medium	2,000 ML/d for 90 days	1.6	4.0	1.4	10.0
Dry	1,500 ML/d for 60 days	3.1	6.0	2.2	10.0
Very Dry	1,000 ML/d for 60 days	3.2	8.8	0.6	10.0

5. Operating regimes

5.1 Introduction

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

- Identifying target environmental 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, interactions with other environmental assets and possible downstream effects such as risk of blackwater events.

5.2 Identifying target environmental flow recommendations

The selection of target environmental flows in each of the different climate years is triggered in this document by the combined Victorian and NSW Murray allocations at the start of July (allocations to Victorian high reliability water shares, Victorian low reliability water shares, NSW high security water shares and NSW general security water shares) as shown in Table 10. Allocations have been used as a surrogate for seasonal river flow conditions. Allocations have been detailed from the start of July as these allocations provide the volumes available for the June–November watering actions proposed in this document (see Table 3 and Table 11).

Using these triggers, very dry years occur approximately 30 per cent of the time, dry years occur approximately 20 per cent of the time, median years occur approximately 18 per cent of the time and wet years occur approximately 32 per cent of the time.

Table 10: Identifying seasonal target environmental flow recommendations.

Climate year for selecting flow recommendations	Combined NSW/Vic Murray system allocation at the start of July
Very dry	Less than 223%
Dry	Greater than or equal to 223% but less than 280%
Median	Greater than or equal to 280% but less than 331%
Wet	331% or more

If flow or resource availability conditions change significantly, such as in a major spring runoff event, consideration could be given to aiming for higher volume events associated with a wetter climate year. The selection of the suite of flow targets should be flexible and in response to conditions in the Murray River, because the flow thresholds for achieving the ecological benefits aligned with each threshold, particularly for the high flow events (floodplain inundation) are not precise.

For all event triggers, reference should also be made to the seasonal forecasts from the Bureau of Meteorology to assess the likely future conditions. Seasonal climate forecasts from the Bureau are available at http://www.bom.gov.au/climate/ahead/rain_ahead.html and seasonal streamflow forecasts are available at http://www.bom.gov.au/water/ssf/.

5.3 Delivery triggers

Suggested operational triggers for delivering the environmental flow proposals are presented in Table 11 including triggers for commencing delivery of each event. All deliveries to extend or initiate events are assumed to occur through Torrumbarry Cutting.

Table 11: Summary of operational regime for achievement of proposed environmental objectives.

Climate year	Flow objective (flow into forest)	Season/ timing	Average return period	Trigger for delivery	Trigger for ceasing delivery (if applicable)
Very dry	1,000 ML/d for 60 days	Jun – Nov	Every very dry year	Commence delivery to extend a commenced event if: • an overbank event occurs naturally • a managed event commences • by 1 September Whichever occurs earlier.	n/a
Dry	1,500 ML/d for 60 days	Jun – Nov	Every dry year	Commence delivery to extend a commenced event if: • an overbank event occurs naturally • a managed event commences • by 1 September Whichever occurs earlier.	n/a
Median	2,000 ML/d for 90 days	Jun – Nov	Every median year	Commence delivery to extend a commenced event if: • an overbank event occurs naturally • a managed event commences • by 1 September Whichever occurs earlier.	If risks to private property and infrastructure are likely.
Wet	6,000 ML/d for 50 days followed by 3,400 ML/d for 55 days	Jun – Nov	Every wet year	Commence delivery to extend a commenced event if: • an overbank event occurs naturally • a managed event commences.	Consider not delivering if 6,000 ML/d event is of short (<7 days) duration and account volumes are low. Also, if risks to private property and infrastructure are likely.

The integration of water delivery to achieve multiple ecological outcomes, for example the coordination of watering events at multiple locations, has not been considered in this document and requires further investigation.

5.4 Wetland Regulators

There are various regulators and effluent creeks which allow water to enter Koondrook-Perricoota Forest from the Murray River. The capacity of the regulators is as shown in Table 12 (MDBA 2010) and locations are shown in Figure 8. The table shows that the regulators and effluent creeks commence to flow when the Murray River downstream of Torrumbarry Weir exceeds 15,000 ML/d. This flow threshold is higher than the 50th percentile daily flow at this site in all months except August (the 50th percentile daily flow for August is 15,286 ML/d).

The operation of the inlet regulators will differ for natural, managed and hybrid events (FNSW 2009):

- Entirely natural events – Swan Lagoon regulator will be open and water will enter the forest via Swan Lagoon and other effluent creeks. The Torrumbarry Cutting regulator will remain closed throughout the event.
- Entirely managed events – Torrumbarry Cutting regulator will be open and water will enter the forest via the Torrumbarry Cutting. Swan Lagoon regulator will remain closed throughout the event.
- Hybrid event – Swan Lagoon regulator will be open and water will enter the forest via Swan Lagoon and other effluents. The Torrumbarry Cutting will be opened as required to supplement or extend the flow event.

Table 12: Wetland regulator and effluent creek capacities (MDBA 2010).

Regulator/effluent creek	Murray River (d/s Torrumbarry) commence to flow (ML/d)	Capacity at Murray River (d/s Torrumbarry) flows of 30,000 ML/d (ML/d)
Swan Lagoon	15,000	4,600
Burrumbury Creek	16,000	Not specified
Fire Hut	18,000	Not specified
Thule	17,000	Not specified
Crooked Creek	During overbank flows only	Not specified
Little Forest	21,500 at Barham	Not specified
CI Lagoon	17,000 at Barham	Not specified
Waddy Creek (Merran Creek)	2,000 at Barham	Not specified
Little Merran Creek (Merran Creek)	1,400 at Barham	1,000

Outflows from the forest can also be regulated. There are four regulators that can be used to pool water in the forest – Barbers overflow, Barbers Creek, Cow Creek and Calf Creek. The sum of the capacity of these four regulators under regulated flow conditions is currently planned to be 250 ML/d. The return channel on Crooked Creek can be used to measure outflows up to 1,850 ML/d from the forest back to the Murray River.

Figure 8: Location of Flow Regulators (MDBA 2010b).

5.5 Storage releases

The release capacities of upstream Murray River storages (Hume Dam, Yarrawonga Weir and Torrumbarry Weir) and Lake Eildon on the Goulburn River are not a constraint to delivering environmental flows to the Koondrook-Perricoota Forest. The physical release capacity of Hume Dam is in excess of the downstream constraints on releases due to flooding of private land. The release capacity of Lake Eildon and both Yarrawonga Weir and Torrumbarry Weir are not a constraint in delivering environmental flows downstream. However, flow constraints at the Barmah Choke will constrain releases to downstream.

Flooding constraints and flow peak attenuation between the storage release points (Hume Dame and Lake Eildon) and Koondrook-Perricoota do however constrain the ability to deliver large releases (such as would be required for overbank flows) to Koondrook-Perricoota. These constraints are discussed further in the following sub-sections.

5.6 Delivery of water for high flow events

The ability to deliver water to the forest from Torrumbarry Weir pool means that flood events can be created or extended under regulated flow conditions without the need to raise the river level above bankfull flow. Koondrook-Perricoota Forest is still likely to receive water under natural floods, and any watering of upstream ecological assets such as the Barmah-Millewa Forest or the Lower Goulburn floodplain could contribute to overbank flooding at Koondrook-Perricoota Forest. The advantage of overbank events is that they have the potential to reach all of the forest, whereas the regulated supply from the Torrumbarry Weir Pool can only reach part of the forest. Significant attenuation of flood peaks occurs as floods pass through the Barmah-Millewa Forest and the Lower Goulburn floodplain. Significant losses of water to these assets can also occur with large uncertainties in the volumes of these losses from event to event. For these reasons no specific strategy is recommended for the delivery of overbank events from further upstream, other than to respond to those events when they occur by extending their duration as required to meet the recommended flows and manage recessions.

5.7 Travel time

The travel time along the Murray River under regulated flow conditions is approximately four days from Hume Dam to Yarrawonga Weir and a further seven days from Yarrawonga Weir to Torrumbarry Weir. Large volumes of regulated releases can also be delivered from Lake Eildon via the Goulburn River. The travel time from Lake Eildon to the Murray River confluence under regulated flow conditions is approximately seven days.

An example of a high flow event for the Murray River downstream of Torrumbarry is shown in Figure 9. This example shows that high flows recorded downstream of Yarrawonga are significantly attenuated by the Barmah-Millewa Forest (some data missing) and contribute to long periods of sustained high flows at Torrumbarry Weir with low rates of rise and fall. Peak flow events recorded on the Goulburn River at McCoys Bridge then contribute to peak events at Torrumbarry on top of the more constant high flows from the Murray River.

Based on the hydrographs at these sites it is difficult to discern the travel time between Yarrawonga and Torrumbarry, however the travel time from McCoys Bridge to Torrumbarry appears to be in the order of six or seven days.

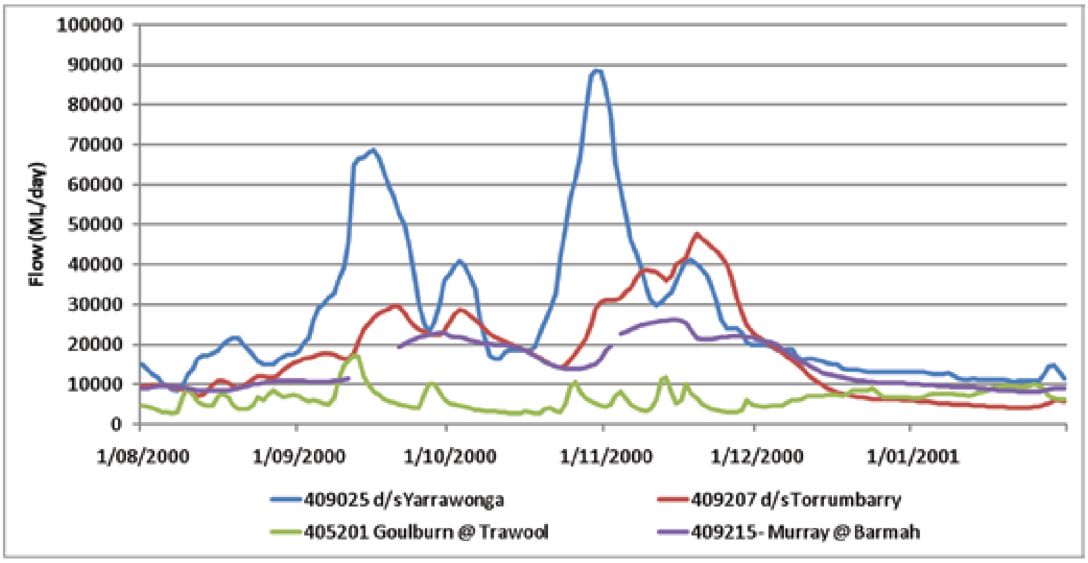


Figure 9: Murray River example event – Spring 2000.

5.8 Flooding

During natural (i.e. overbank) flooding events, outflow from Koondrook-Perricoota Forest is primarily through Thule, Barbers, Calf and Cow Creeks which return flows to the Murray River via the Wakool System. FNSW (2009) notes that during large flood events water also drains from the forest via Axe and Pothole Creeks and floods into some adjoining private property.

As a part of the flood enhancement works, downstream structures are being constructed to regulate water flowing out of the forest. In terms of flooding impacts, a levee is being constructed around the downstream perimeter of the forest to protect adjoining properties from flooding. The location of this 43 kilometre levee is shown as the dashed line on Figure 8. The levee has a level of 78.8 mAHD. Its height varies from zero to approximately four metres above the floodplain (FNSW 2010). Despite the construction of the levy, there are still some potential flooding issues in the vicinity of Barbers Creek and outflows from the downstream regulators will need to be managed to avoid any local flooding in this area. The 250 ML/d is the current cumulative planned limit on releases from the downstream regulators and is specified to prevent this flooding. This means that flows from other regulators accumulating at Barbers Creek regulator should not create flows in excess of 250 ML/d at Barbers Creek regulator. Barbers Creek has several blockbanks which are used to pool water for diversion to landholders. If bywashes are constructed around the blockbanks, then up to approximately 500 ML/d may be released from the regulators.

Forests NSW is currently investigating opportunities to increase releases from the forest up to 2,000 ML/d, which is an approximate bankfull flow in the creek. This would potentially require alternative access to be provided to landholders to enable the blockbanks to be removed, together with a range of other measures (L.Broekman, Forests NSW, pers.comm. 21/4/11). Resolving these flooding issues will be important for improved delivery of environmental flows, as the full 6,000 ML/d capacity through the Torrumbarry Cutting cannot currently be utilised for the desired duration due to the outlet flow constraints.

5.9 Weir flow control

The desired maximum 6,000 ML/d of flow through the Torrumbarry Cutting is achievable when the Torrumbarry Weir pool is within 5 centimetres of full supply level. The weir pool may be drawn down occasionally for maintenance or flood control, which could occasionally limit environmental water managers' ability to use the cutting.

5.10 Interactions with other assets

The Koondrook-Perricoota Forest forms part of the Central Murray Floodplain which includes Gunbower Forest, Barmah-Millewa Forest, Lower Goulburn floodplain and the Edward-Wakool system. Deliveries of water to these upstream and adjacent assets have the potential to interact with flow behaviour in the Koondrook-Perricoota Forest through the provision of overbank flows or the ability to re-divert return flows re-credited to environmental water managers from upstream. Water from the Koondrook-Perricoota Forest can interact with the lower Wakool system via effluent creeks near Barham and downstream ecological assets on the Murray River, such as the Lindsay, Mulcra and Wallpolla Islands.

The flow recommendations in this document are consistent with those for Gunbower Forest in that all deliveries are proposed under regulated flow conditions.

5.11 Water Delivery Costs

5.11.1 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.

Any water sourced from Victorian water shares for delivery to the Koondrook-Perricoota Forest would first be transferred to a NSW Murray system account and State Water's delivery costs would apply.

5.11.2 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 planning and management services, including managing the quantity and quality of water available to water users. In 2011–12 these charges for the NSW Murray system are $0.90/ML for usage and $1.38/ML of entitlement per unit share.

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

5.11.3 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. 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 Koondrook-Perricoota Forest include:

- NSW Office of Environment and Heritage as the manager of the Adaptive Environmental Water and Murray Additional Environmental Allowance (AEA) in the Water Sharing Plan for the NSW Murray and Lower Darling Regulated Rivers Water Sources.
- MDBA as the operator of the Murray system storage, weirs and locks.
- State Water Corporation as operator of the water delivery infrastructure.
- Forests NSW as operators of the flow regulators into and out of Werai Forest.
- Murray Catchment Management Authority as a stakeholder in the development and implementation of watering plans.
- Victorian Department of Sustainability and Environment and NSW Office of Environment and Heritage as holders of water for the Barmah-Millewa Allowance.
- NSW Office of Water as managers of the NSW water resource.

6.2 Approvals, licenses, legal and administrative issues

6.2.1 Water shepherding and return flows

Return flows from the Koondrook-Perricoota Forest are significant and have been estimated to be 70–84 per cent of delivered flows (FNSW et al. 2008). Similarly, return flows from delivery of water to upstream ecological assets could potentially be re-used to deliver water to Koondrook-Perricoota Forest. There are a number of regulators that will be constructed as a part of the flood enhancement works to return flows to the system. These include:

- The return channel and Crooked Creek regulator return flows directly to the Murray River and have the ability to regulate return flows of up to 1,850 ML/d (FNSW 2009), which suggests that not all return flows from the forest are expected to pass via this mechanism.

- Other downstream regulators including Thule Creek regulator, Calf Creek regulator, Cow Creek regulator, Barbers Creek regulator and Barbers Overflow regulator which return flows to the Wakool System. During managed watering events these regulators will be used to retain water in the forest, rather than pass water downstream. During managed watering events up to 250 ML/d may be passed to Barbers Creek, however flows should not exceed this figure in order to prevent flooding. During natural watering events, all regulators will be operated to maintain natural flow paths through, and out of, the forest.

The monitoring of these regulators, discussed further in Section 9, will allow accurate accounting of return flows and net water use in the forest during managed events.

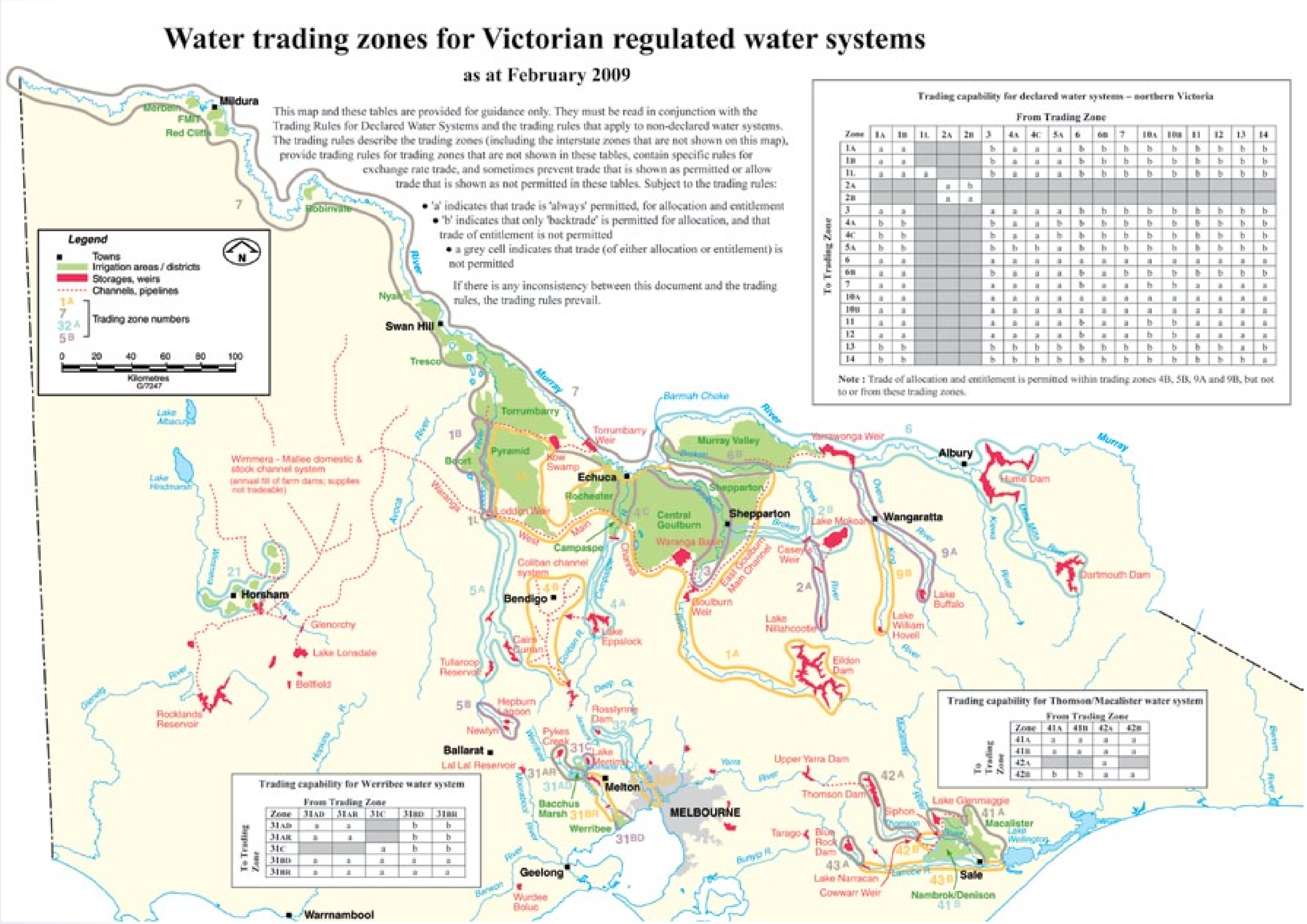
In NSW, Section 45 of the Water Sharing Plan for the NSW Murray and Lower Darling Regulated Rivers Water Sources (which recommenced from 1 July 2011) allows water allocations to be re-credited in accordance with return flow rules established under Section 75 of the *Water Management Act 2000 (NSW)*. Under the present water sharing arrangements within the context of the Murray-Darling Basin Agreement and NSW Water Sharing Plan rules, gaining "recredits" for water in the Murray River downstream of the Koondrook-Perricoota Forest are not possible. However, water released for environmental purposes may be passed through NSW and not diverted for consumptive use as part of the NSW resource at times when the NSW Murray is in a period of unregulated flow. This would not strictly result in a re-credit, but would amount to the entitlement allocation not being used in NSW at the time therefore rendering it available to be accounted downstream of the forest. Any such arrangement would require an application to the NSW Commissioner of Water.

In these situations NSW consults with Victoria via the Water Liaison Working Group on the effects of the sharing of losses and inflows relevant to each individual State water shares. NSW Office of Water needs time to prepare how it will manage the water resources it has at its disposal and as such applying for water to be treated in this manner should be undertaken early in the planning process (D.Jacobs, NOW, pers.comm. 29/07/11).

6.3 Trading rules and system accounting

6.3.1 Water trading

A map of the trading zones for the southern Murray-Darling Basin is shown in Figure 10.



Trading capability for declared water systems – northern Victoria (From Trading Zone across; To Trading Zone down)

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

Trading capability for Werribee water system (From Trading Zone across; To Trading Zone down)

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

Trading capability for Thomson/Macalister water system (From Trading Zone across; To Trading Zone down)

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

Figure 10: Trading zone boundaries (source: http://waterregister.vic.gov.au/Public/Documents/trading_zones_map.pdf).

Koondrook-Perricoota Forest is located in Trading Zone 11 (NSW Murray below Barmah Choke).

From Trading Zone 11, allocation and entitlement trade can occur to:

- Zone 6: Victorian Murray Dartmouth to Barmah
- Zone 7: Victorian Murray Barmah to South Australia
- Zone 10A: NSW Murray above Barmah
- Zone 10B: Murray Irrigation Limited
- Zone 11: NSW Murray below Barmah (within system trade)
- Zone 12: South Australian Murray.

From Trading Zone 11, allocation trade up to the volume of back trade to date (but no entitlement trade) can occur to:

- Zone 1A: Greater Goulburn
- Zone 1B: Boort
- Zone 3: Lower Goulburn
- Zone 4A: Campaspe
- Zone 4C: Lower Campaspe
- Zone 5A: Loddon
- Zone 6B: Lower Broken Creek
- Zone 13: Murrumbidgee
- Zone 14: Lower Darling.

The volume of back trade at any given time is listed at: www.waterregister.vic.gov.au/Public/Reports/InterValley.aspx

Allocation and entitlement trade can occur into Trading Zone 11 from:

- Zone 1A: Greater Goulburn
- Zone 1B: Boort
- Zone 3: Lower Goulburn
- Zone 4A: Campaspe
- Zone 4C: Lower Campaspe
- Zone 5A: Loddon
- Zone 6B: Lower Broken Creek
- Zone 7: Victorian Murray Barmah to South Australia
- Zone 11: NSW Murray below Barmah (within system trade)
- Zone 12: South Australian Murray
- Zone 13: Murrumbidgee
- Zone 14: Lower Darling.

Allocation trade up to the volume of back trade to date (but no entitlement trade) can occur into Trading Zone 11 from:

- Zone 6: Victorian Murray Dartmouth to Barmah
- Zone10A: NSW Murray above Barmah
- Zone 10B: Murray Irrigation Limited.

Additional Trading Rules

All trade (except to unregulated tributaries) is with an exchange rate of 1.00. Trade into Murray Irrigation Limited Areas (Trading 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. 8/12/10).

Permanent trade is currently limited to 4 per cent per year from irrigation districts in Victoria. Goulburn-Murray Water advises via media releases when these limits are reached for individual irrigation districts. There are various exemptions for this limit specified in the trading rules on the Victorian Water Register. For more information on water trading rules, see the Victorian Water Register (http://waterregister.vic.gov.au/).

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

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

This means that environmental water managers must make any allocation trades well in advance of a targeted runoff event.

Water trading attracts water trading fees. If the Australian Government conducts its own water trading 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.

6.3.2 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 carryover rules are based on the Water Sharing Plan for the NSW South Wales Murray and Lower Darling Regulated Rivers Water Sources, which was suspended between 2006 and 30 June 2011 due to prolonged drought 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. In the Victorian Murray, unlimited storage carryover is allowed, but water above 100 per cent of the water share volume can be quarantined in a spillable water account when there is risk of spill. Any water in the spillable water account cannot be accessed until the risk of spill has passed. If a spill occurs, water in the Spillable Water Accounts is the first to spill. Annual deduction for evaporation is 5 per cent of the carried over volume. The fee for transferring water from the spillable water account back to the allocation bank account is $4.52/ML for the Murray system. See http://www.g-mwater.com.au/customer-services/carryover#1 for more information.

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

6.4 Water use plans

There are a number of plans that are currently in development or in draft stage for environmental water management in the Koondrook-Perricoota Forest. The MDBA is developing the Koondrook-Perricoota Icon Site Environmental Water Management Plan to guide the use of environmental water under the Living Murray (MDBA in prep). Forests NSW have developed a Preliminary Operating Plan (draft) as part of the Flood Enhancement Project (FNSW 2009) for the management of regulated floods into the forest via the planned infrastructure works. In addition, Koondrook-Perricoota Forest is identified as a hydrological indicator site for the development of the Murray-Darling Basin Plan (MDBA 2010).

The environmental water provisions in the Water Sharing Plan for the New South Wales Murray and Lower Darling Regulated Rivers Water Sources 2003 are implemented by the OEH. The plan sets out provisions for planned environmental water (Barmah-Millewa Allowance, Barmah-Millewa Overdraw, Lower Darling Environmental Contingency Allowance, and a Murray Regulated River Water Source Additional Environmental Allowance and Adaptive Environmental Water). Of these only the Murray Regulated River Water Source Additional Environmental Allowance and Adaptive Environmental Water are of direct relevance to the Koondrook-Perricoota Forest, though in most instances some water from the Barmah-Millewa Allowance would flow through to the forest.

The OEH intends to produce an Annual Watering Plan for each regulated water source in which they have a decision making role. This watering plan will cover use of Environmental Water Allowances and any licences nominated as Adaptive Environmental Water (DECW 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 Valley.

7. Risk Assessment and mitigation strategies

Potential risks of delivering environmental water to the Koondrook-Perricoota Forest were assessed as part of the Flood Enhancement Project (GHD 2010). The risk assessment outlined in Table 13 provides an indication of these risks. 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. A framework for assessing risks has been developed by SEWPaC and is included at Appendix 4.

The most significant risk is to receiving waters, such as the Wakool River and to a lesser extent, Murray River, from blackwater events. Releases of water from floodplain forests can result in low dissolved oxygen blackwater events as organic matter on the floodplain surface is rapidly metabolised by microorganisms (Baldwin 2009; Gilligan et al. 2009). This poses a serious risk to native fish and significant fish deaths have resulted from this process as recently as spring and summer 2010–11. However the risk to native fish (and other aquatic fauna) from low dissolved oxygen can potentially be mitigated by careful management to ensure sufficient flushing flows, and timing of water releases during cooler months rather than during summer.

The flooding of Koondrook-Perricoota Forest in spring 2010 resulted in the movement of organic matter that had accumulated on the floodplain over 16 years. There is therefore a lower likelihood of a widespread blackwater event from floodplain inundation in the next year or two, as there has been less time for litter to accumulate on the floodplain surface over time. An appropriate environmental watering regime will avoid organic build up and so will also help to mitigate this risk.

Environmental flows may also result in an increase in the abundance and types of invasive species within the system. Carp (*Cyprinus carpio*) are already present in the system, and experience from adjacent areas such as Barmah-Millewa has shown that floodplain inundation can favour carp spawning and recruitment (Stuart and Jones 2002). In addition, floodwaters can carry propagules for invasive plant species, and it is possible that native macrophytes could be displaced by invasive species such as arrowhead (*Sagittaria graminea*). However, the increased risk from environmental water delivery (above normal river operations) on the spread of invasive species is unknown. Weeds such as arrowhead, which favour stable water levels, may well already be distributed through the suitable habitat the system and would not survive periods of dry conditions, if transported into intermittent and ephemeral streams and wetlands.

A rapid reduction in river discharge interrupts plant growth and fauna breeding and can strand fish on the floodplain. Environmental watering options have been developed to mitigate this risk by releasing environmental water to reduce recession rates. However, rapid recession is also a risk associated with environmental water releases and may occur if a watering event is interrupted. When environmental watering events are planned, the rate of recession should be considered and measures put in place to minimise the risk of rapid recession.

Table 13: Risk associated with water delivery in the Koondrook-Perricoota 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.	Unlikely – Likely, depending on antecedent conditions in floodplain.	Major	High	Blackwater risks may be reduced by: • providing recommended floodplain inundation regimes that avoid sustained periods without flooding • avoiding 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 decrease the abundance of arrowhead should be explored.
Acid sulphate soils	Conditions throughout the forests are not considered likely to contain potential ASS.	Rare	Moderate	Low	None required.
Rapid recession	A rapid fall in water levels can lead to a reduction in recruitment of fish and waterbirds, as well as impacts to wetland flora.	Possible	Moderate	Medium	Design environmental releases with a suitable flood recession.
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.
Flooding of private land	Releases from the downstream regulators into Barbers Creek must pass through private land and have the potential to cause flooding under some circumstances.	Possible	Moderate	Medium	Environmental water managers to be updated of investigations by Forests NSW on this issue.

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 was suspended in November 2006 due to prolonged drought conditions but recommenced on July 1 2011. Water sharing is administered by the NSW Office of Water.

The adaptive environmental water allocated under the water sharing plan is overseen by OEH. Annually, OEH prepares an adaptive environmental water plan for the Murray Valley (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 Valley and Lower Darling. This includes representatives from the Murray CMA, Lower Murray-Darling CMA, Murray-Darling Freshwater Research Centre, Murray Lower Darling Customer Service Committee, NSW Murray Darling Wetlands, State Water Corporation, NSW Office of Water, NSW Office of Environment and Heritage, Department of Primary Industries (Fisheries), the Murray Lower Darling Rivers Indigenous Nations (MILDRIN) and Forests NSW.

Structures in the Koondrook-Perricoota Forest are controlled by Forests NSW under the direction of the MDBA and operated by State Water.

8.1.2 Environmental water provisions

Minimum flow requirements are not specified in the water sharing plan for the NSW Murray and Lower Darling Regulated Rivers Water Sources, rather a volume of water is allocated to the environment as Adaptive Environmental Water. Similarly, the Victorian environmental entitlements do not specify minimum channel flows in the Murray River.

During the irrigation season, flows in the Murray River are generally running above natural streamflows because of irrigation deliveries. During the non-irrigation season, minimum flows in the Murray River are provided from Victorian tributaries.

Minimum flows from Victorian tributaries downstream of the Barmah-Millewa Forest are outlined in the water delivery documents for the Lower Goulburn floodplain and the Campaspe River. This includes:

- Minimum flows in Goulburn-Murray Water's Goulburn River Bulk Entitlement, which requires a minimum average monthly flow at the McCoys Bridge gauging station of 350 ML/d for the months of November to June inclusive (at a daily rate of no less than 300 ML/d) and 400 ML/d for the months of July to October inclusive (at a daily rate of no less than 350 ML/d). Refer to Peter Cottingham & Associates and SKM (2011).
- Minimum flows of 20–70 ML/d in the Campaspe River from the Campaspe Siphon to the Murray River as specified in Goulburn-Murray Water's Campaspe System Bulk Entitlement. Refer to Peter Cottingham & Associates and SKM (2011b).
- No minimum flows specified for Broken Creek outflows, however minimum flows are often delivered along Broken Creek to manage water quality. Refer to Peter Cottingham & Associates and SKM (2011c).

Whilst not specified in the water sharing plan or environmental entitlements, minimum Murray River flows are maintained for operational purposes. Downstream of Yarrawonga Weir a minimum flow of 1,800 ML/d is maintained "to provide minimum flows for riparian and water quality requirements" (MDBA 2010). When releases drop below 4,000 ML/d irrigation deliveries at Moira Lake are affected and 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 2010). The MDBA notifies these parties if minimum flows drop below these values.

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

8.1.3 Current water holdings

Commonwealth environmental water holdings (as at October 2010) in the southern Murray-Darling Basin connected system are summarised in Table 14. Licences have been identified separately upstream and downstream of the Barmah Choke, as this can sometimes be a restriction on trade. The volume available downstream of the Choke is up to approximately 308 GL whilst licences above the Choke can provide up to an additional 194 GL if traded to downstream of the Choke, although trade from upstream to downstream of the Choke is limited. Note that the Murrumbidgee, Loddon, Victorian Murray and South Australian allocations would need to be traded to the NSW Murray downstream of the Choke prior to use for Koondrook-Perricoota Forest.

Table 14: 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
	0.0	
Goulburn	64,919.6	High reliability water share
	10,480.0	Low reliability water share
Broken***	0.0	
	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**

* Commonwealth environmental water holdings includes 70.0 ML of regulated river entitlement on the Ovens System, however this water cannot be traded outside of the Ovens Basin.

** Commonwealth environmental water holdings includes 20,820 ML of supplementary water shares on the Murrumbidgee System, however this water cannot be traded outside of the Murrumbidgee Basin.

*** Commonwealth environmental water holdings includes 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 downstream of the Choke by other agencies is listed in Table 15. Only volumes downstream of the Choke have been listed as these other water shares are generally tied to use at specific locations which may preclude trading to downstream of the Choke from upstream of the Choke. This table indicates that significant volumes of water could be available from other environmental entitlements in the Murray River downstream of the Choke. This does not include any water delivered to Barmah-Millewa Forest and along the Goulburn River under The Living Murray and State government entitlements, which can potentially contribute several hundred gigalitres more environmental water to the Murray River at Torrumbarry Weir.

Table 15: Environmental water currently held by other agencies in Murray River downstream of Barmah Choke.

Water holding	Volume	Comments
Water Sharing Plan for the NSW Murray and Lower Darling Regulated Rivers Water Sources **– Adaptive Environmental Water**	30,000 unit shares conveyance (broadly equivalent to ~15,000 ML high security and ~15,000 ML low security) 2,027 unit shares high security (2,027 ML)	The plan was suspended but recommenced from 1 July 2011.
Water Sharing Plan for the NSW Murray and Lower Darling Regulated Rivers Water Sources **– Murray Additional Environmental Allowance**	0.03 ML per unit share of high security (~6,000 ML)	Can be carried over and up to 28,000 ML.
Murray River – Flora and Fauna Conversion Further Amending Order (2009) – **Flora and Fauna** (Victoria)	27,600 ML high reliability water share	
Murray River – Flora and Fauna Conversion Further Amending Order (2009) – **The Living Murray** (Victoria)	2,080 ML high reliability water share 58,537 ML low reliability water share 34,300 ML unregulated flow	Unregulated flow entitlement only available when MDBA declares its availability.
The Living Murray – NSW Murray system	1,887 high security 134,387 general security 350,000 ML supplementary 12,965 ML unregulated	Unclear how much of this is above or below the Choke.
Minister for Environment (in Trust for Snowy Recovery) – **Snowy Environmental Reserve** (Victoria)	29,794 ML high reliability water share	Unclear how much of this is above or below the Choke.

8.2 Seasonal allocations

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

State Water and the MDBA calculate available water determinations every month, which are then confirmed and issued by the NSW Office of Water. Current water availability for the NSW Murray can be found at: http://www.water.nsw.gov.au/Water-management/Water-availability/Available-water-determinations/default/aspx. A register of historical announcements is listed at http://www.water.nsw.gov.au/Water-management/Water-availability/Water-allocations/Available-water-determinations-2010-11/default.aspx and related pages, however the historical announcements are 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 11 and Figure 12. 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 CSIRO, but has reliability between the high and low security licences. This information is sourced from the MSM-Bigmod post-TLM run (#22061) and matches historical water availability in the very dry years of 2007 and 2008.

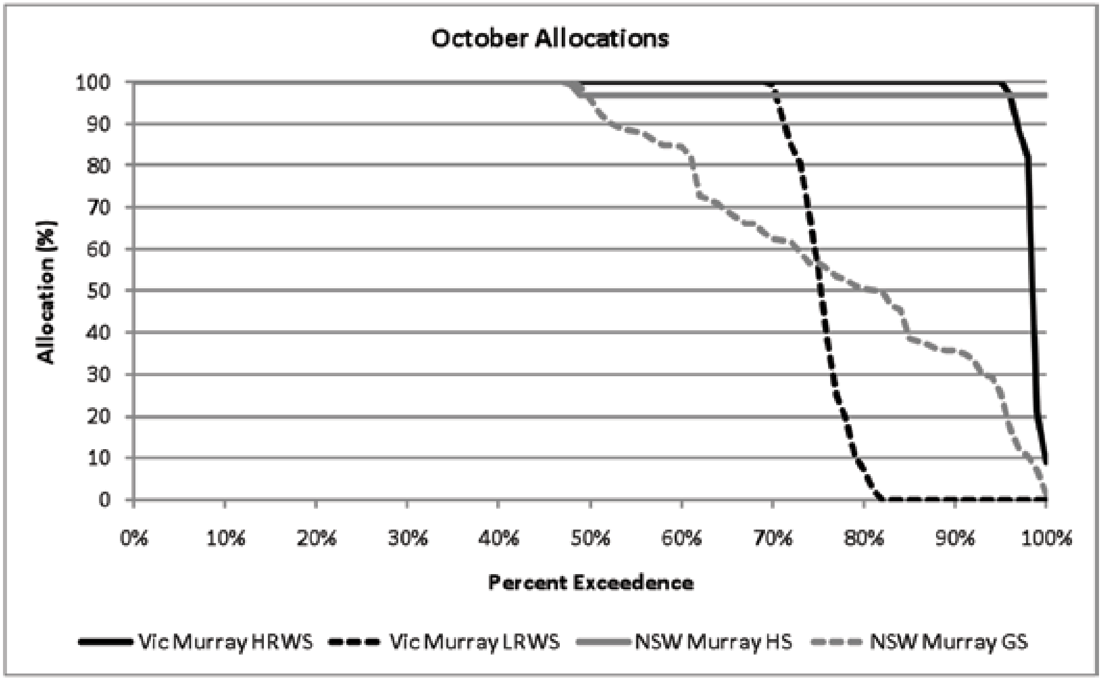


Figure 11: October seasonal allocations for the Murray system.

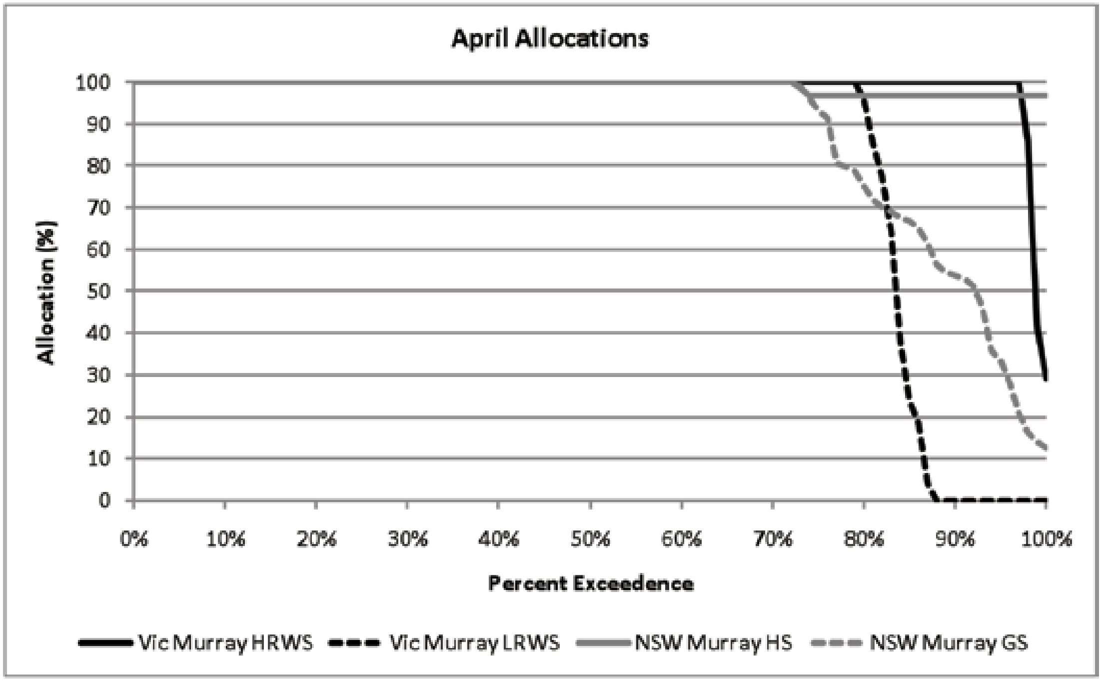


Figure 12: April seasonal allocations for the Murray system.

The allocation expected to be available (in terms of announced allocation) to the environment under different climate conditions is summarised in Table 16. The volume of water expected to be available to the environment under different climate conditions is summarised in Table 17 based on October 2010 water holdings. 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).

The tables show, for example, that the Commonwealth Government could expect to have minimal (less than 1,000 ML) water available in the NSW Murray River below the Choke in spring in a very dry year and 33,000 ML of water available below the Choke in a wet year. If water is traded from other locations within the connected southern Murray-Darling Basin, then up to 53,000 ML could be available in spring in a very dry year and up to 501,000 ML could be available in spring in a wet year, subject to any trading constraints.

Tables 16 and 17 were provided by SKM and based on allocation information from a MSM-Bigmod model of the Murray River system with The Living Murray deliveries in place (run #22061).

Table 16: Likely allocation against 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 17: Likely volume available to the environment from 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

Under normal conditions for the New South Wales Murray NOW 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. Allocation announcements are generally made on the 15th of each month (or the next business day), however when allocations to high reliability water shares are less than 100 per cent 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 opening October and February allocations for the following season. The seasonal allocation outlooks are published on Goulburn-Murray Water's website (see Media Releases http://www.g-mwater.com.au/news/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 evaluation and improvement

9. Monitoring evaluation and improvement

9.1 Existing monitoring programs and frameworks

Condition monitoring is undertaken annually at Living Murray Icon sites, which includes the Koondrook-Perricoota Forest. Most recent reports are for the condition of river red gum and black box communities (Cunningham et al. 2009) and waterbirds (Kingsford and Porter 2009).

Environmental monitoring of managed flood events through the Flood Enhancement Works is the responsibility of Forests NSW. Monitoring plans are being developed under the Koondrook-Perricoota Icon Site Environmental Watering Plan (MDBA in prep). Forests NSW undertook inundation mapping during the first peak of the 2010 spring flood event, which will provide useful baseline data (Figure 13; Linda Broekman, FNSW, pers. comm.).

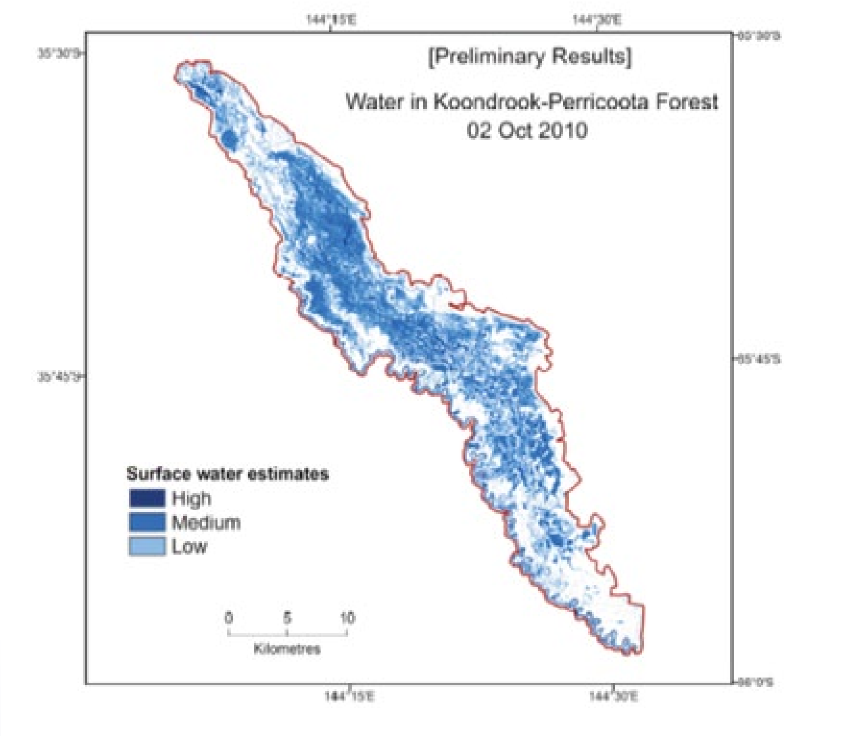


Figure 13: Example of inundation monitoring undertaken by Forests NSW in 2010.

9.1.1 Flow monitoring sites

There are various measuring points for environmental water relevant to Koondrook-Perricoota Forest, as listed in Table 18. This includes a combination of streamflow monitoring along the Murray River and from the main tributaries downstream of Hume Dam, and flow and water level monitoring into and out of the 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 18: Flow monitoring in the Murray River near Koondrook-Perricoota Forest.

Site number	Site name	Relevance
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
409006	Murray River at Picnic Point	Flows through the Choke d/s Gulpa Ck
404210	Broken Creek at Rices Weir	Flows from Broken Creek
409215	Murray River at Barmah	Flows d/s of Barmah-Millewa Forest
405232	Goulburn River at McCoys Bridge	Flows from Goulburn River
406202	Campaspe River at Rochester	Flows from Campaspe River
409219	Murray River at Torrumbarry Weir	Water level and volume in weir pool
409207	Murray River d/s Torrumbarry Weir	Flows d/s Torrumbarry Weir
409209	Murray River at Cohuna	Flows in Murray River mid-forest
409005	Murray River at Barham	Murray River d/s of Gunbower Forest and upstream of Campbells Island
409044	Little Merran Creek at Franklings Bridge	Flows in Merran Creek d/s of cutting that connects Merran Creek to the Murray River anabranch around Campbells Island
409214	Murray River at Pental Island	Murray River d/s of Campbells Island
414200 A	Murray River below Wakool Junction	Flows out of the forest in the Wakool and Murray
409062	Wakool River and Gee Gee Bridge	Flows out of the forest via Thule, Barbers, Cow and Calf Creeks

Flow monitoring may also include sites in the forest after the construction of the Torrumbarry Cutting. Environmental water managers should update the above list of sites once the cutting has been constructed and new gauging stations have been established. State Water has indicated that during scheme operation they would expect to measure the following variables (FNSW 2010):

- Inflows through the inlet regulator.
- Outflows through Swan Lagoon, Thule Regulator, the Return Channel and the four downstream structures near Barbers Creek (either at the structures or downstream at Gonn Road).
- Pool level.
- Possibly inflow to the top of the pool.

The location of the proposed flow monitoring is shown in Figure 14.

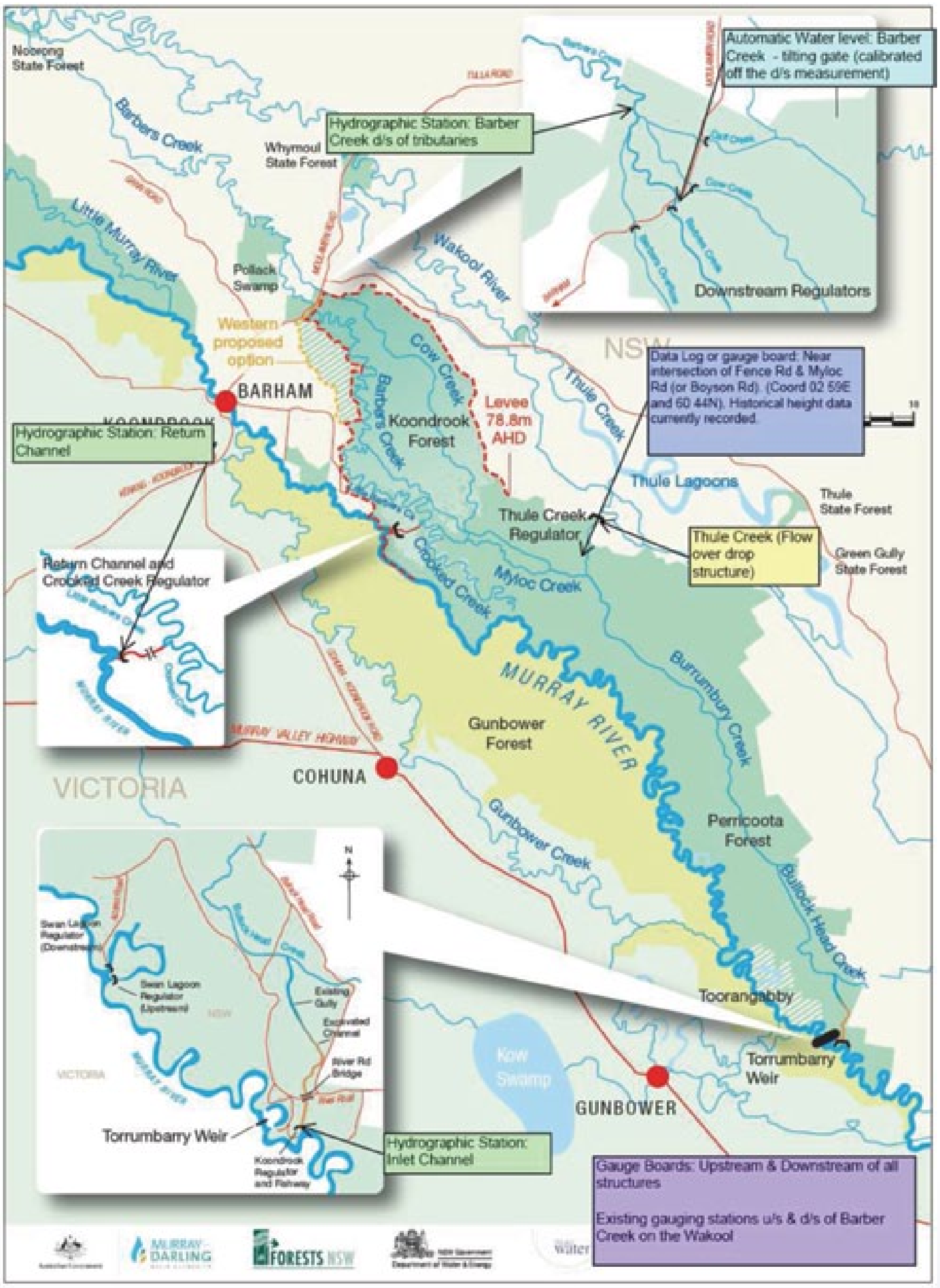


Figure 14: Proposed Flow Monitoring (FNSW 2010).

9.2 Operational water delivery monitoring

FNSW, State Water and OEH will provide a log of actions in any watering event to provide environmental flows. Environmental water managers should request that FNSW, State Water and OEH commence documentation of watering events as they occur and finalise documentation as soon as the watering event has been completed. The Commonwealth's pro-forma for an operational monitoring report is contained in Appendix 2. This information can provide input into future environmental water delivery, as well as any applications for return flow credits to the NSW State Government.

9.3 Key parameters for monitoring and evaluating ecosystem response

Potential monitoring for the management of environmental water in the Koondrook-Perricoota Forest is summarised in Table 19.

Table 19: Monitoring plan for environmental water use.

Ecological objectives	Hypotheses	Water scenarios	Indicator(s)	Monitoring sites	Frequency	Linkages and responsibility
Maintain the extent and enhance condition of aquatic vegetation.	Proposed watering regime will maintain extent and improve condition of aquatic vegetation.	Extreme dry, Dry, Median, Wet.	Vegetation extent and community composition.	Pollacks Swamp, Swan Lagoon, Horseshoe Lagoon.	Seasonally	TLM icon site condition monitoring includes extent and composition of understorey vegetation.
Maintain the extent and enhance condition of river red gum forests and woodlands.	Regular (two to five 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.	Koondrook-Perricoota Forest.	Annually	TLM condition monitoring includes stand condition and vegetation extent at icon sites including Gunbower / Koondrook-Perricoota.
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 condition monitoring includes fish monitoring at icon sites including Gunbower / Koondrook-Perricoota.
Support waterbird breeding by provision of feeding and nesting habitat.	Inundation of wetlands and floodplains for three to four months will instigate successful waterbird breeding.	Median, Wet.	Abundance, nest counts, fledgling success.	Pollacks Swamp, broader floodplain.	Event driven	Both ground and aerial surveys are incorporated into TLM icon site condition monitoring.
Provide habitat for aquatic fauna.	Proposed water regime will provide habitat for aquatic fauna.	Extreme dry, 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 condition monitoring includes frog and turtle monitoring at icon sites including Gunbower / Koondrook-Perricoota.
Prevent excessive build-up of organic matter on the floodplain surface to minimise impacts to receiving waters.	Restoring an adequate floodplain inundation regime prevent excess accumulation of litter and reduce blackwater events.	Median, Wet.	Dissolved oxygen (DO).	Effluent streams and downstream waters: Murray and Wakool Rivers.	DO monthly during inundation	DO measured by NSW Office of Water algal monitoring program and Murray River System Scale monitoring.

10. Opportunities

The watering actions proposed in this document use the Torrumbarry Cutting to deliver water to the forest, rather than relying on overbank flows. This reduces the volume of water required to be delivered, however large volumes of water are still needed. There may be potential for further works to be undertaken within the forest to re-distribute water within the forest, increasing the area watered and/or reducing the volume of water required. It may be suitable to investigate the potential for such works in the future.

Delivery to Campbells Island is not possible via existing flood enhancement works. There may be an opportunity to build infrastructure on the floodplain to deliver water to Campbells Island.

The risk of flooding downstream of the four outlet regulators flowing into Barbers Creek currently constrains the water releases to no more than 250 ML/d. This in turn places a constraint on the ability to deliver water through the Torrumbarry Cutting at the maximum flow rate for an extended duration. Forests NSW is currently looking into options to improve the conveyance along Barbers Creek so that higher flow rates can be released from the downstream regulators without flooding. These options include bypassing block banks (to achieve maximum releases up to around 500 ML/d) to providing alternative supplies to landholders so that the block banks can be removed (to achieve maximum releases of around 2,000–4,000 ML/d), as well as other potential measures. Improving the conveyance of outflows along Barbers Creek will help environmental water managers to achieve their ecological objectives, particularly for the designated wet year events.

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Appendix 1: Significant flora and fauna

Significant species in the Koondrook-Perricoota Forest (GHD 2009).

Common Name	Scientific Name	EPBC Status	TSA Status	Presence
Australasian bittern	*Botaurus poiciloptilus*		Vulnerable	Known to occur
Australian painted snipe	*Rostralula australis*	Endangered	Endangered	Likely
Barking owl	*Ninox connivens*		Vulnerable	Known to occur
Black-chinned honeyeater	*Melithreptus gularis gularis*		Vulnerable	Known to occur
Brown treecreeper	*Glossopsitta pusilla*		Vulnerable	Known to occur
Bush stone-curlew	*Burhinus grallarius*		Endangered	Known to occur
Caspian tern	*Sterna caspia*	Marine, Migratory		Known to occur
Cattle egret	*Ardea ibis*	Marine, Migratory		Known to occur
Common greenshank	*Tringa nebularia*	Marine, Migratory		Known to occur
Diamond firetail	*Stagonopleura guttata*		Vulnerable	Known to occur
Eastern great egret	*Ardea modesta*	Marine, Migratory		Known to occur
Forked-tailed swift	*Apus pacificus*	Migratory		Known to occur
Gilbert's whistler	*Pachycephala inornata*		Vulnerable	Known to occur
Glossy ibis	*Plegadis falcinellus*	Marine, Migratory		Known to occur
Grey-crowned babbler	*Pomatostomus temporalis temporalis*		Vulnerable	Known to occur
Hooded robin	*Melanodryas cucullata*		Vulnerable	Known to occur
Latham's snipe	*Gallinago hardwickii*	Migratory		Known to occur
Little lorikeet	*Glossopsitta pusilla*		Vulnerable	Likely
Magpie goose	*Anseranas semipalmata*		Vulnerable	Known to occur
Malleefowl	*Leipoa occelata*	Endangered		Known to occur
Marsh sandpiper	*Tringa stagnatilis*	Marine, Migratory		Known to occur
Plains-wanderer	*Pedionomus torquatus*	Vulnerable	Endangered	Known to occur
Red-necked stint	*Calidris ruficollis*	Marine, Migratory		Known to occur
Regent honeyeater	*Xanthomyza phrygia*	Endangered	Vulnerable	Known to occur
Sharp-tailed sandpiper	*Calidris acuminata*	Marine, Migratory		Known to occur

Common Name	Scientific Name	EPBC Status	TSA Status	Presence
Speckled warbler	*Pyrrholaemus saggitatus*		Vulnerable	Known to occur
Superb parrot	*Polytelis swainsonii*	Vulnerable	Vulnerable	Likely
Swift parrot	*Lathamus discolor*	Endangered	Vulnerable	Likely
White-bellied sea eagle	*Haliaeetus leucogaster*	Marine, Migratory		Known to occur
White-throated needletail	*Hirundapus caudacutus*	Migratory		Known to occur
Murray cod	*Maccullochella peelii peelii*	Vulnerable	Vulnerable	Known to occur
Macquarie perch	*Macquaria australasica*	Endangered	Endangered	Likely
Little pied bat	*Chalinolobus picatus*		Vulnerable	Known to occur
Spotted-tailed quoll	*Dasyurus maculatus*	Endangered	Vulnerable	Likely
Large-footed Myotis	*Myotis adversus*		Vulnerable	Known to occur
Eastern long-eared bat	*Nyctophilus timoriensis*	Vulnerable	Vulnerable	Likely
Squirrel glider	*Petaurus norfolcensis*		Vulnerable	Known to occur
Brush-tailed phascogale	*Phascogale tapoatafa*		Vulnerable	Known to occur
Koala	*Phascolarctos cinereus*		Vulnerable	Known to occur
Yellow-bellied sheathtail bat	*Saccolaimus flaviventris*		Vulnerable	Known to occur
Floating swamp wallaby-grass	*Amphibromus fluitans*	Vulnerable	Vulnerable	Known to occur
A spear-grass	*Austrostipa wakoolica*	Endangered	Vulnerable	Likely
Winged peppercress	*Lepidium monoplocoides*	Endangered	Endangered	Likely
Slender darling pea	*Swainson murrayana*		Vulnerable	Likely

Appendix 2: 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 two 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 3: Baseline streamflows at key locations

Streamflows (ML/d) for the Murray River downstream of Hume Dam (1895–2009).

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

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	631	453	690
Feb	0	217	345	479
Mar	0	193	310	482
Apr	18	282	426	630
May	0	552	721	1,128
Jun	179	852	1,336	2,084

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

Streamflows (ML/d) for the Murray River downstream of Yarrawonga Weir (1895–2009).

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

Streamflows (ML/d) for the Murray River at Barmah (1895–2009).

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

Streamflows (ML/d) for Broken Creek at Rices Weir (1895–2009).

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

Streamflows (ML/d) for the Goulburn River at McCoys Bridge (1895–2009).

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

Streamflows (ML/d) for the Campaspe River at Rochester (1895–2009).

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

Streamflows (ML/d) for the Murray River downstream of Torrumbarry Weir (1895–2009).

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

Streamflows (ML/d) for the Loddon River downstream of Kerang Weir (1895–2009).

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

Streamflows (ML/d) for the Murray River at Barham 1895–2009).

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

Streamflows (ML/d) for the Murray River at Pental Island 1895–2009).

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

Appendix 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.

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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

WAT090 0211

Australian Government

Commonwealth Environmental Water

ENVIRONMENTAL WATER DELIVERY

Lachlan River

DECEMBER 2011 V1.0

Image Credits

The next generation of straw-necked ibis at Booligal breeding colony
© Paul Packard

Aerial view of the Lachlan
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Barma Water Resources in association with Thurtell L and Wettin P (2011). *Environmental Water Delivery: Lachlan River.* Prepared for Commonwealth Environmental Water, Department of Sustainability, Environment, Water, Population and Communities, Canberra.

ISBN: 978-1-921733-38-3

SEWPaC acknowledges the following organisations and individuals that have been consulted in the preparation of this document:

Ben Gawne, Murray Darling Freshwater Research Centre
Sri Sritharan, State Water Corporation
Sandy Circuitt, previous owner of Lake Waljeers
Paul Packard, NSW Office of Environment and Heritage.

Published by the Commonwealth Environmental Water Holder for the Australian Government.

ENVIRONMENTAL WATER DELIVERY

Lachlan River

DECEMBER 2011 V1.0

Environmental Water Delivery: Lachlan River system

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

- 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 Lachlan River catchment. As the first version of the document, it is intended to provide a starting point for discussions on environmental water use. As such, suggestions and feedback on the document are encouraged and will be used to inform planning for environmental water use and future iterations of the document.

The Lachlan supports important ecological values including over 470,000 hectares of wetlands. Potential water use options for the Lachlan include delivering water to Muggabah Creek to improve hydrological connectivity within the Booligal wetland system as well as providing low-level inundation of the lower Lachlan and associated wetlands, including Lake Ita and Lake Waljeers. Environmental water could also be used to support colonial nesting waterbird breeding events, should they occur.

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 New South Wales Office of Environment and Heritage, and the State Water Corporation.

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.

Commonwealth Environmental Water
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Abbreviations

AEW	Adaptive environmental water
CAMBA	China–Australia Migratory Bird Agreement
CEWH	Commonwealth Environmental Water Holder
CMA	Catchment Management Authority
COAG	Council of Australian Governments
CSIRO	Commonwealth Scientific and Industrial Research Organisation
CTF	Commence-to-fill
NSW I&I	NSW Department of Industry and Investment
DEWHA	Australian Government Department of the Environment, Water, Heritage and the Arts
DIPNR	NSW Department of Infrastructure Planning and Natural Resources
DLWC	NSW Department of Land and Water Conservation
DPI	NSW Department of Primary Industries
DSE	Victorian Department of Sustainability and Environment
DWR	NSW Department of Water Resources
EPBC	Environment Protection and Biodiversity Conservation Act 1999 (Cwlth)
ECA	Environmental contingency allowance
EW	Environmental water
EWAs	Environmental water allowances
EWR	Environmental Water Holder
FNSW	Forests New South Wales
GCS	Great Cumbung Swamp
GS	General security
IQQM	Integrated Quantity and Quality Model
IMEF	Integrated Monitoring of Environmental Flows program
ISRAG	Independent Sustainable Rivers Audit Group
IUCN	International Union for Conservation of Nature
JAMBA	Japan-Australia Migratory Bird Agreement
LCMA	Lachlan Catchment Management Authority
LEWMP	The Lachlan Environmental Water Management Plan

LRWG	Lachlan Riverine Working Group
MCA	Multi-criteria analysis
MEP	Monitoring Evaluation Plan
MDB	Murray-Darling Basin
MDBA	Murray-Darling Basin Authority
MLD EWAG	Murray Lower Darling Environmental Water Advisory Group
MWWG	Murray Wetlands Working Group
NSW	New South Wales
NOW	NSW Office of Water
OEH	NSW Office of Environment and Heritage
RERP	Rivers Environmental Restoration Program
ROKAMBA	Republic of Korea-Australia Migratory Bird Agreement
SEWPaC	Australian Government Department of Sustainability, Environment, Water, Population and Communities
SRA	Sustainable Rivers Audit
TLM	The Living Murray program
WMA	Water Management Area
WSP	Water Sharing Plan

PART 1:
Management aims

1. Overview

1.1 Scope and purpose of this document

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 water-use options for large volumes of environmental water.

To maximise the systems' 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 project, assets and potential watering options have been identified for regions across the Murray-Darling 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 options have been developed for each asset to meet watering objectives under a range of volume scenarios. Use of environmental water will aim to maximise environmental outcomes at multiple assets, where possible. Water-use options will provide an 'event ready' basis for the use of environmental water. Options are expected to be integrated into a five-year water delivery program.
3. Processes and mechanisms that are required to operationalise environmental water-use strategies are documented and include such things as:
   - delivery arrangements and operating procedures
   - water-delivery accounting methods that are either currently in operation at each asset 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 focuses on the delivery of water to the Lachlan system to achieve positive environmental outcomes.

1.2 Catchment and river system overview

The Lachlan River covers 8 per cent of the Murray-Darling Basin. It is bordered by the Great Dividing Range on the east, the Macquarie River to the north, by the Murrumbidgee River to the south and the Darling catchments in the north-west. The catchment is a virtual-terminal system, with the Lachlan River ending in the extensive wetlands of the Great Cumbung Swamp (Figure 1). A more detailed map of the lower Lachlan wetlands is provided in Figure 2.

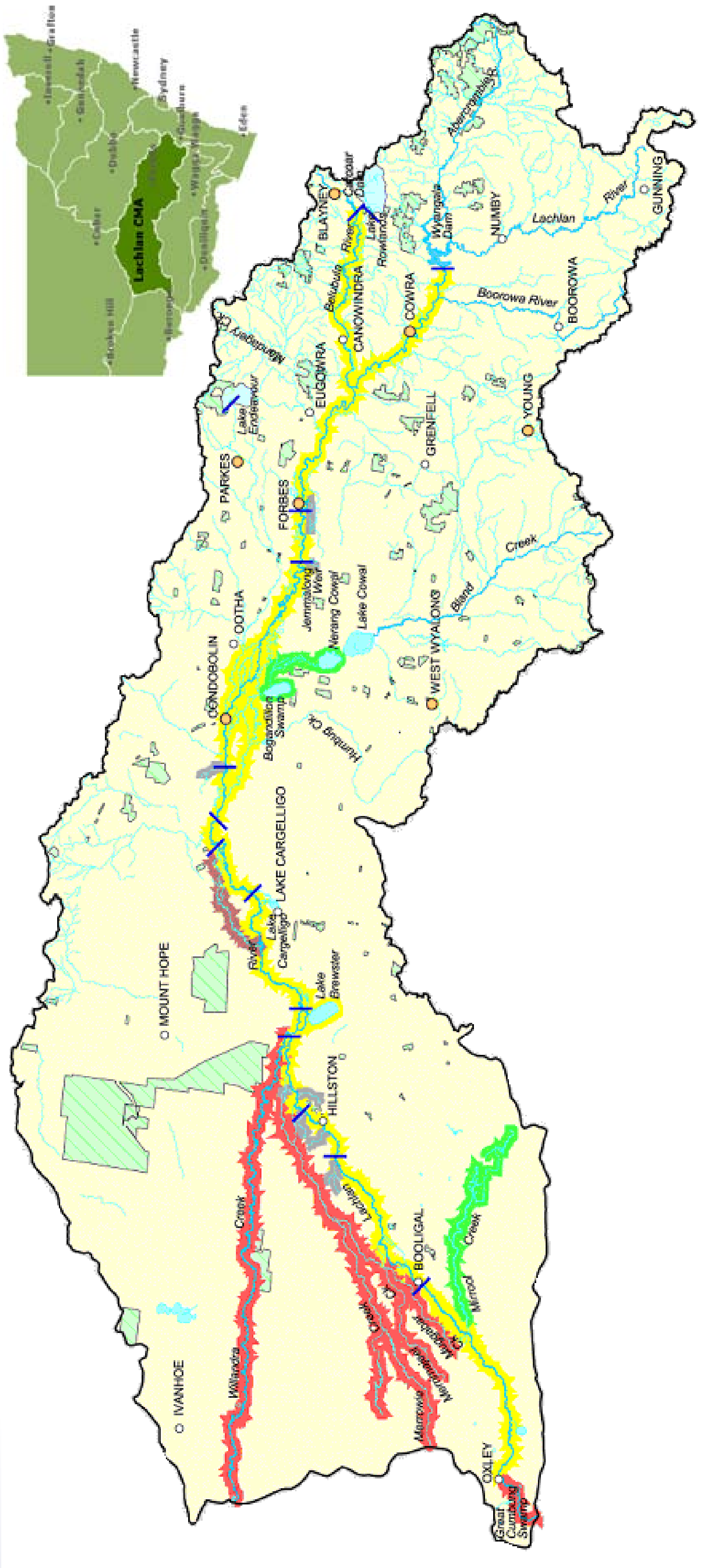

Figure 1: Lachlan catchment

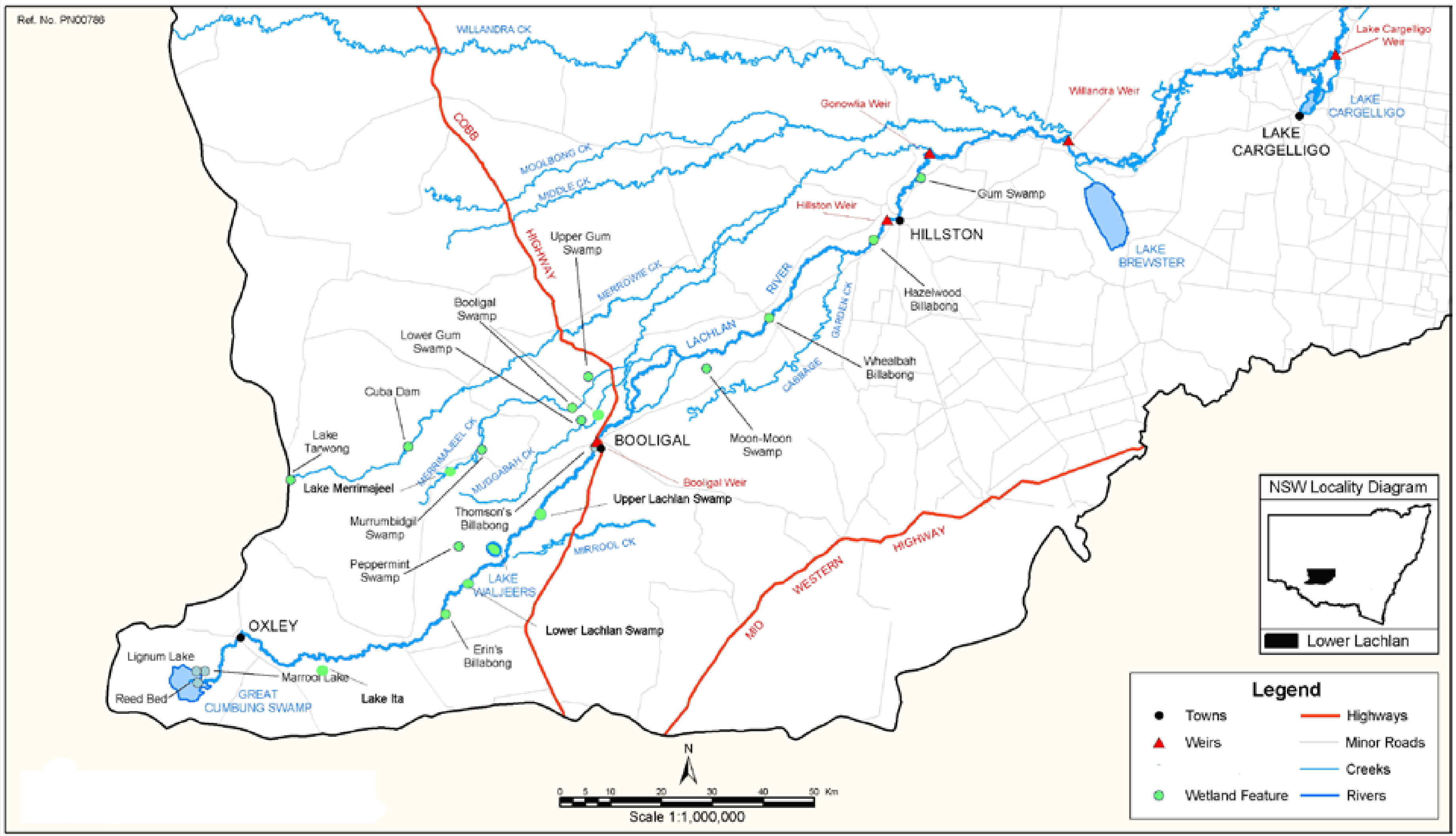

Figure 2: Lower Lachlan wetlands—detailed map

The catchment's major water storage is the Wyangala Dam with a storage capacity of 1,218,000 megalitres. There are a series of minor in-stream storages along the Lachlan, including the Carcoar Dam (36,000 megalitres) and Brewster Weir (5,500 megalitres). Major off-stream storages include Lake Cargelligo (36,000 megalitres) and Lake Brewster (145,000 megalitres[1]) near Hillston. Recently, works have been undertaken at Lake Brewster to change its storage characteristics, so the storage capacity is uncertain—see section 6.3.

Floodplain wetlands cover some 400,000 hectares along the river, starting downstream of Forbes with the Lake Cowal system, billabong habitats in the Condobolin anabranch section and large wetland systems downstream of Lake Brewster. The wetlands also cover effluent creeks (Figures 1 and 2).

There are nine nationally important wetlands in the Lachlan catchment:

- Booligal Wetlands
- Murrumbidgil Swamp/Lake Merrimajeel (part of the Booligal Wetlands system)
- Cuba Dam
- Merrowie Creek (Cuba Dam to Chilichil Swamp)
- The Great Cumbung Swamp
- Lachlan Swamp (part of mid-Lachlan wetlands)
- Lake Brewster
- Lake Cowal/Wilbertroy Wetlands
- Lower Mirrool Creek Floodplain (Mirrool Creek is a tributary of the Lachlan which joins the river downstream of Booligal and upstream of the Lachlan Swamps; the downstream portion of the creek is an integral part of water management for the Murrumbidgee Irrigation Area, e.g. Barrenbox Swamp).

The Lachlan Environmental Water Management Plan (LEWMP) also identifies nine regionally significant wetlands that represent areas which have been recognised for their contribution to the Lachlan landscape. The regionally important wetlands include:

- Lake Cargelligo
- Lake Ita (as part of the Lachlan Swamp)
- Burrawang West Lagoon
- Willandra Creek
- Moon Moon Swamp
- Yarnel Lagoon
- Baconian Swamp (as part of the Cumbung)
- Upper Merrowie Creek
- Mid-Lachlan Floodplain and Billabongs.

1 The Lake Brewster water storage has recently undergone a series of works to reconfigure the storage to try and improve the quality of water releases and its effective storage capacity (see asset profile and information in section 6.3). After many years of being dry, storage of water in the lake has only recently occurred and will also continue with the current flood events. Therefore at this time the actual storage capacity of the lake is unknown and will be established as operational knowledge increases.

1.3 Overview of river operating environment

In developing this document, efficient use and delivery of environmental water is a primary consideration. In this context the following background is relevant and is based (but not entirely) on information from BWR (2010), a study which examined the water delivery and ecological conditions for six wetland areas (Moon Moon Swamp, Murrumbidgil Swamp, Lake Merrimajeel, Lower Gum Swamp, Ita Lake and Baconian Swamp) as of winter 2009.

The Lachlan is a very long river with many anabranches and distributary (effluent) creeks both in the section near Condobolin and primarily on the lower river downstream of Lake Brewster. Consequently, the river's channel capacity varies significantly, with it becoming a smaller channel particularly around the Condobolin anabranch area, and progressively downstream of Lake Brewster due to the effects of the distributary channels. (Section 5.1.3 provides details on channel capacities.)

Sources of environmental water in the Lachlan are an important consideration when assessing delivery efficiency. The river regulation storages where this water would reside are Wyangala Dam, Lake Cargelligo, Lake Brewster and Brewster Weir. The storage capacities of the lakes are relatively small compared to Wyangala Dam and historically both reach very low levels each year. The two re-regulating lakes and Brewster Weir are the closest to the target wetlands and are traditionally used to supply stock and domestic water to the downstream river and some creeks, and for some irrigation extraction largely around Hillston. On nearly all occasions in the past, Lake Brewster releases have been used to support colonial waterbird breeding events at Booligal Swamp.

It is important to emphasise that the existence of the two re-regulating storages of Lake Cargelligo and particularly Lake Brewster has major implications for the operation of the Lachlan River. When water is stored in Lake Brewster the river operates as two rivers, that is, Wyangala to Brewster Weir and Brewster Weir to Oxley. When Lake Brewster is empty, the river is operated from Wyangala Dam.

Other sources of water for the Lachlan River come from tributary streams which enter the river below Wyangala Dam, with the main ones being:

- Boorowa River, which enters the river upstream of Cowra
- Belabula River, which is partially regulated by Carcoar Dam, and enters the river downstream of Cowra
- Mandagery Creek which enters the river at Eugowra
- Goobang Creek which enters the river downstream of Forbes
- Mirrool Creek which very rarely provides flows downstream of Booligal.

For the unregulated flows upstream of Lakes Cargelligo and Brewster, it is important to note that these flows provide a highly natural flow regime for the many kilometres of river channel. The filling of these lakes and re-regulation of flows can have a significant influence on the downstream flow regime.

1.4 Environmental water policy on the Lachlan

Environmental water was first provided on an informal ad hoc basis in 1984 to sustain a waterbird-breeding event at Booligal Swamp. This arrangement continued until 1992 when a water policy for the river was established, with provisions for 100,000 megalitres and later an 80,000-megalitre environmental contingency allowance in Wyangala Dam. This water was available on a reactive basis for waterbird breeding events and water quality reasons.

In 1998, environmental flow rules were adopted as part of NSW water reforms. These flow rules established up to 350,000 megalitres of translucency environmental flows, which were subsequently adopted (with some changes) in the Water Sharing Plan (see section 2.1). The flow rules also established a 10,000 ML/yr environmental contingency allowance with carryover provisions. These rules operated from 1998 to the end of the 2003 water year and were subsequently adopted (with some changes) by the 2004 Water Sharing Plan (see section 2.1).

Translucent flows were released from Wyangala Dam in 1998, however these were subsequently subsumed by large flood events that year. Smaller translucency events occurred in 1999. The full 350,000 megalitres of translucency flow were provided in 2000, followed by another 105,000 megalitres in 2001. The Lachlan then entered a very dry period, with no translucent flows occurring under the Water Sharing Plan which was suspended in 2004 and did not recommence until 1 July 2011, the beginning of the 2011–12 water year.

More information on translucency flows can be found in section 2.1.

1.5 Water Sharing Plan provisions for environmental water

The NSW Water Sharing Plan commenced on 1 July 2004, but was soon suspended due to record low inflows to the system. The NSW Office of Water implemented drought contingency rules from 2004 until the end of the 2010–11 water year, due to major inflows into the river. Water Sharing Plan rules for the Lachlan were reinstated on 1 July 2011.

Details of the environmental water provisions are provided in section 8.1.

1.6 Flow characteristics

Mean annual flow of the Lachlan River is around 1,325 GL/yr and exhibits extreme variability. Prior to river regulation the Lachlan had long periods of no flow, including sites as far upstream as Cowra, with examples outlined below (DLWC 1998):

- Cowra—no flow for 111 days between March to June 1908
- Forbes—no flow for 224 days between December 1898 to July 1899
- Booligal—no flow for 228 days between December 1919 to July 1920.

No flow periods no longer occur at Cowra and Forbes and are rare at Booligal. The natural flow regime of the river under unregulated conditions was dominated by high flows in winter and spring, with low flows in summer and autumn. River regulation and water use on the Lachlan has affected the flow regime, although it retains elements of the natural regime.

Figure 3 and Table 1 illustrate the change in flows at selected sites.

Table 1: Change in flows on the Lachlan River under unregulated and regulated conditions (DLWC 1998).

Location	Unregulated winter daily mean flow (ML/d)	Regulated winter daily mean flow (ML/d)	Unregulated summer daily mean flow (ML/d)	Regulated summer daily mean flow (ML/d)
Forbes	5,220	3,800	1,130	2,170
Condobolin	3,890	2,790	965	1,350
Booligal	1,020	570	542	340
Oxley	565	295	549	340

Note: These modelled data were prior to the summer irrigation, mostly cotton growing, becoming more popular in the Lachlan and likely does not represent current circumstances. Similar model outputs for current conditions would need to be provided by the NSW Office of Water.

1.7 Irrigation demand

Irrigation demand is spread along the Lachlan River but has two areas of concentration, namely at Jemalong Weir where bulk diversions are made to the Jemalong Irrigation Area, and around Hillston where there has been major growth in irrigation over the past 20 years. The Hillston irrigation is from both river and groundwater sources. There is very little irrigation downstream of the Whealbah area which is located downstream of Hillston.

1.8 Flow-monitoring sites

There are a large number of flow-monitoring stations along the regulated Lachlan River and also the effluent creeks. The NSW Office of Water's real-time website provides information on these sites, and also a wide range of flow data and water quality information on the Lachlan catchment. See http://realtimedata.water.nsw.gov.au/water.stm.

1.9 Hydrology modelling

The NSW Office of Water's Lachlan Integrated Quantity and Quality Model (IQQM) is used to represent flow relationships for the regulated river. The model can be used for a wide range of scenarios for different water sharing and distribution arrangements for the river's main channel. Recently, Barma et al. (2010) developed hydrology models for the NSW Office of Water for 19 wetland systems downstream of Hillston and it is now possible to extend the river water sharing and distribution scenario modelling arrangements to these wetlands. These models could be used to examine different scenarios for environmental water use patterns and outcomes.

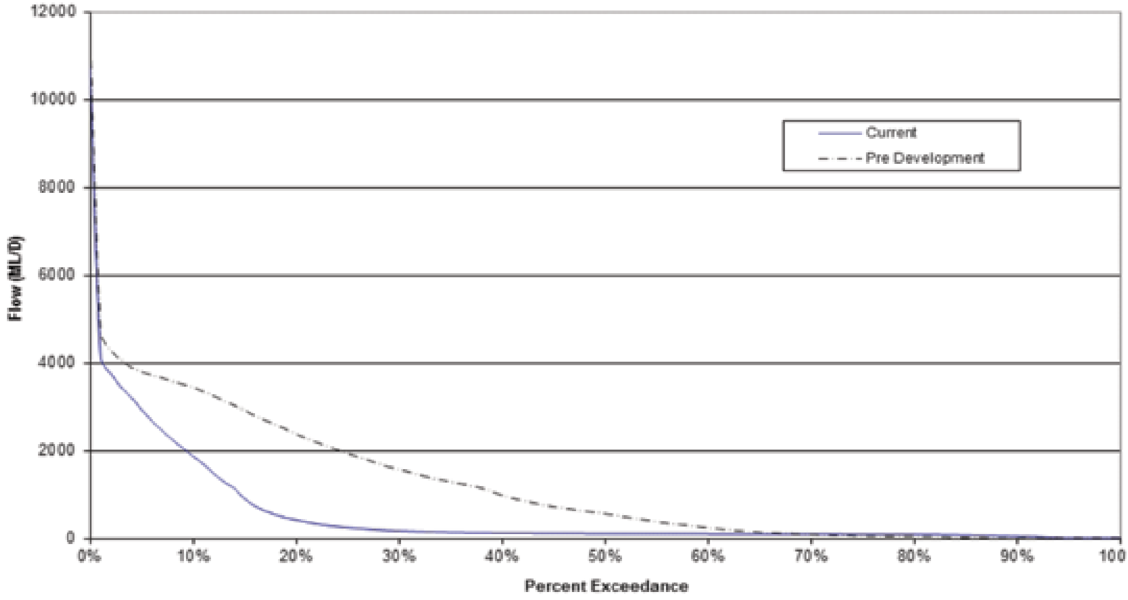

Figure 3: Change in Lachlan River flow regime at Booligal

2. Ecological values, processes and objectives

The Lachlan catchment is a unique region within the Basin. The Lachlan River, under average flow conditions, terminates in wetlands and distributary creeks, with channels extending up to 180 kilometres in length. The Lachlan catchment is the only terminal system in the Basin, and its streams and wetlands support important riverine ecosystems and an array of wildlife (Lachlan Catchment Management Authority (LCMA) 2006).

The Lachlan region supports approximately 470,000 hectares of wetlands, 95 per cent of which occur on the lower Lachlan floodplain (Armstrong, Kingsford & Jenkins 2009). As a result of water regulation and agricultural development, riparian zones and floodplains in the Lachlan have been greatly altered and disconnected. This disconnection has caused a decline in the health of some wetlands, associated riparian zones and habitat. Riparian and wetland condition has also been affected by the introduction of a number of exotic species (e.g. willow trees, lippia and carp). The Lachlan wetlands on the lower river floodplain are of regional and national importance because they support large colonial waterbird breeding events as well as a number of rare, endangered and vulnerable species (CSIRO 2008).

The entire aquatic ecological community of the lower Lachlan River, which is defined as the Lachlan River downstream of Wyangala to the Great Cumbung Swamp, is listed as an endangered ecological community in NSW under the provisions of the *Fisheries Management Act 1994* (NSW). Historically, this area has supported a diverse aquatic community comprising at least 19 native fish species, 10 crustacean species, 8 mollusc species, 2 sponge species and many insects (DPI 2006). River regulation, land management practices (e.g. riparian clearing) and species introductions, however, have resulted in substantial modifications to aquatic habitats in the lower Lachlan and the abundance and distribution of many aquatic species have exhibited considerable reductions. In particular, four native fish species (Macquarie perch, trout cod, southern pygmy perch and purple-spotted gudgeon) and the freshwater river snail are listed in the schedules of the *Threatened Species Conservation Act 1995* (NSW) as either endangered, vulnerable or with endangered populations in the western region.

Under the *Fisheries Management Act 1994* (NSW), the key threatening factors that affect the lower Lachlan aquatic ecological community are in-stream structures and other mechanisms that alter natural flow, exotic species and the degradation of native water-dependent vegetation.

The key values of a catchment are defined as the ecological components, processes and sites of significance known to contribute to the essential character of the catchment. In the Lachlan these have been identified as riparian areas as they filter sediments and pollutants, slow run-off and provide wildlife habitat, and are the last line of defence for aquatic ecosystems from terrestrial inputs. Other values of the catchment include:

- waterbirds, native fish and frogs and their habitats
- semi-permanent wetland vegetation, such as river red gum forest, reed grasslands, black box woodlands
- gilgai depressions
- open-water lagoons
- a chain of ponds or swampy meadows in the upper catchment.

Waterbirds are a valued component of the Lachlan catchment, making up a large proportion of the faunal biomass within the lower catchment. Waterbirds tend to have preferred locations and vegetation for shelter and nest sites. Species that have been recorded using habitats within the lower Lachlan, and that are under international agreements, include the great egret, glossy ibis, bar-tailed godwit, common greenshank, common sandpiper, Latham's snipe, long-toed stint, painted snipe and the white-bellied sea-eagle (see Appendix 1). In 2010–11 there were two substantial colonial nesting waterbird breeding events, predominantly involving straw-necked ibis in the lower Lachlan and a major pelican breeding event in Lake Brewster.

The minimum requirement for successful colonial nesting waterbird breeding is flooding of sufficient volume and duration to inundate colony sites and feeding areas for a minimum of four to five months between August and March. These flows are also critical for maintaining wetland vegetation, and for the completion of life cycles of aquatic invertebrates (Jenkins 2006).

A number of important native fish species are also known to occur in the Lachlan catchment. These include the Macquarie perch, Murray cod, silver perch, olive perchlet and purple-spotted gudgeon (see Appendix 1).

Important fish habitats have been identified in the Lachlan, including the Lachlan River around Warroo Bridge, the Lachlan River and Goobang Creek near Condobolin, the Lachlan River and Mountain Creek near Brewster Weir and the Lachlan River between Gonowlia and Booligal Weirs. Recently a population of 2,000 olive perchlets have been stocked into the river upstream of Lake Cargelligo Weir to try and re-establish this species. These fish were sourced from the Mountain Creek population (DPI 2011).

A number of threatened and/or endangered frog species have been recorded in the Lachlan catchment. These includes the yellow-spotted bell frog (*Litoria castenea*) which was recently discovered in the Southern Tablelands of the upper Lachlan catchment. The yellow-spotted bell frog is listed as critically endangered under the *Threatened Species Conservation Act 1995* (NSW) and as endangered under the *Environmental Protection and Biodiversity Conservation Act 1999* (Cwlth). Another threatened species, the southern bell frog (*Litoria raniformis*), was previously known to occur in the catchment but has not been recorded in the area over recent years (Wassens 2005). This frog species is associated with many wetland types, preferring slow-flowing natural water bodies containing emergent aquatic vegetation. Sloane's froglet (*Crinia sloanei*) is listed as a vulnerable species under the *Threatened Species Conservation Act 1995* (NSW), and was recorded in an area around Merrowie Creek during the 2010 replenishment (see section 2.1 on Water Sharing Plan) and environmental flows (P Packard (OEH) 2011, pers. comm.).

In addition, Yarnel Lagoon and Burrawang West are known to support breeding populations of a number of other frog species including the barking marsh frog (*Limnodynastes fletcheri*), Peron's tree frog (*Litoria peronii*), the inland banjo frog (*Lymnodynastes interioris*) and the desert tree frog (*Litoria rubella*) (Wassens & Maher 2010). The delivery of appropriate flows to these wetlands is essential to maintaining these important frog populations.

Extensive river red gum floodplain forests and woodlands form a distinctive and important part of the floodplain character of the Lachlan. The community was assessed by Benson (2006) as "vulnerable" at the landscape level, as approximately only 50 per cent of its extent (prior to European settlement) remains in western NSW. River red gum is important because it provides waterbird nesting sites and habitat for many animals, including woodland birds.

After prolonged drought in the Lachlan, large areas of river red gums became extremely stressed. By 2010 a substantial percentage of the river red gums, previously identified as stressed, had apparently died. A study on the effect of river regulation on river red gums on the Booligal Wetlands indicated that there had also been a significant decline in river red gum populations in that area as a result of river regulation (Armstrong, Kingsford & Jenkins 2009). However, following the flooding in 2010–11 there is anecdotal evidence of a significant recovery in the health of at least some river red gum trees.

The drought has also resulted in the nature of some areas of river red gum woodland and forest changing, with an increase in the area of understorey species suited to drier conditions, such as dryland grasses and chenopods. One indicator of changing flow regime in parts of the lower Lachlan is the colonisation of some areas of river red gum woodland by dryland species, including saltbush.

Extensive stands of common reed (approximately 4,000 hectares) are a distinctive part of the character of the Great Cumbung Swamp, which is listed in the *Directory of Nationally Important Wetlands*. Common reed is known to provide a wide range of habitats and is a major drought refuge. To maintain vigour, it is estimated that flooding is required at least one in every five years (Roberts & Marston 2000).

Another important semi-aquatic vegetation species is water couch, providing habitat and food for a large variety of fauna. It does not tolerate grazing well when water stressed, or when persistently grazed under water. However, recent research suggests that under suitable flow conditions, grazing is a factor in maintaining the dominance of water couch in grassy wetland communities (Wilson et al. 2008).

Black box occurs most commonly in the ephemeral wetland vegetation zone in the Lachlan. Black box woodland is found on flat to slightly undulating landscapes on alluvial soils within rainfall ranges of between 250 millimetres to 450 millimetres a year, and is generally bordered by river red gum or grassland ecosystems. It may also be associated with an understory of saltbushes and short-lived herbs and grasses, with occasional patches of lignum. It provides valuable waterbird breeding habitat, especially for ibis, and has also been assessed by Benson (2006) as being "vulnerable" in NSW.

Less dominant species are also associated with lower Lachlan floodplains, including river cooba, coolibah and myall. Little is known about the ecology of river cooba (*Acacia stenophylla*), which in the Lachlan is mostly found in the lower catchment and is often associated with river red gum or lignum. The species provides valuable nesting habitat, especially for colonial nesting species (Kingsford & Johnson 1998; Kingsford & Auld 2005). Coolibah–black box woodland is listed as an endangered ecological community (EEC) under the *Threatened Species Conservation Act 1995* (NSW), and coolibah open woodland is considered by Benson (2006) to be an "endangered" plant community in NSW. Coolibah occurs in some wetter parts of marsh areas in association with river red gum, although the plant occurs more commonly in less frequently flooded sites, between river red gum and black box woodlands.

Myall or weeping myall woodland is listed as an endangered ecological community under the *Threatened Species Conservation Act 1995* (NSW). Only 14 per cent of the extent (prior to European settlement) of weeping myall woodland remains in NSW and has been assessed by Benson (2006) as an "endangered" plant community. Despite its endangered status, little is known of the ecological requirements of myall. The structure and composition of the community varies, particularly with latitude, as saltbush is more prominent in the western areas of the Lachlan catchment, while other woody species and summer grasses are more common further east. In some areas the shrub stratum may have been reduced or eliminated by clearing or heavy grazing.

Gilgai depressions are small ephemeral pools, usually only a few metres across and less than 30 centimetres deep, and are reasonably common through the mid-and-lower Lachlan. They often support weeping myall, belah (*Casuarina cristate*), black box, bimble box, rosewood (*Alectryon oleifolius*) and river cooba (*Acacia stenophylla*).

Gilgais have been used by graziers to seasonally graze stock in areas that lack permanent water, but are now generally considered a nuisance by many farmers as the movement of soil associated with gilgai formation has been known to damage infrastructure (including building foundations, roads and railway lines, and the undulations produced interfere with crop harvesting). However, gilgais remain of great ecological significance as a source of water for animal and plant life in the Lachlan.

Open water areas exist across the Lachlan floodplain, with notable lagoons including Lake Merrimajeel, and Lignum and Marrool Lakes in the Great Cumbung Swamp. Open water areas provide important habitat for large-bodied fish species and waterbirds and, as they tend to be more permanent water bodies within an ephemeral landscape, can provide drought refuge for a variety of plant and animal species. Open water areas, or pelagic zones, can be divided into the euphotic zone (measured from the surface to where light ceases to penetrate) and the profundal zone (where light does not penetrate). Phytoplankton tend to dominate in the euphotic zone and provide food for zooplankton and fish. The benthic zone, or lake bottom, also provides food and habitat through sediments and accumulated detrital material.

Chains of ponds or swampy meadows were once common in the upper Lachlan catchment. They are generally located in alluvial valley floors not drained by continuous channels, and are characteristically vegetated with dense tussock grass and sedge plants. These permanently or periodically water-saturated environments have been dramatically degraded in the upper Lachlan since European settlement, resulting in these complex systems becoming incised gullies. This has resulted in significant consequences such as loss of sediment through erosion, altered hydrology, loss of biodiversity and a decline in agricultural productivity.

A table of key species found in the Lachlan is presented in Appendix 1.

The Department of Sustainability, Environment, Water, Population and Communities (SEWPaC) has developed objectives for the use of environmental water (DEWHA 2009). These objectives are to guide the use of environmental water under different climatic and flow conditions, often in conjunction with other water to meet ecological objectives related to Lachlan assets. Ecological objectives specifically relating to the delivery of environmental water in the Lachlan at the broad-scale level have been summarised in Table 2. These objectives are incorporated into the delivery scenario objectives presented in section 5.2.

The broad-scale objectives describe the desired outcomes across the many Lachlan assets under different flow scenarios. The ecological objectives were created for individual Lachlan assets in relation to the relevant broad-scale objectives. These objectives guide water-use strategies for the Lachlan.

Table 2: Ecological and management objectives for environmental water use under different water resource availability scenarios (DEWHA 2009).

	Extreme dry	Dry	Median	Wet
Ecological watering 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.
Management objectives	Avoid critical loss of threatened species and communities. Maintain key refuges. Avoid irretrievable damage or catastrophic events.	Support the survival and growth of threatened species and communities including limited small-scale recruitment. Maintain diverse habitats. Maintain low-flow river and floodplain functional processes in sites and reaches of priority assets.	Enable growth, reproduction and small-scale recruitment for a diverse range of flora and fauna. Promote low-lying floodplain-river connectivity. Support medium-flow river and floodplain functional processes.	Enable growth, reproduction and large-scale recruitment for a diverse range of flora and fauna. Promote higher floodplain-river connectivity. Support high-flow river and floodplain functional processes.
Management actions	Water refugia and sites supporting threatened species and communities. Undertake emergency watering at specific sites of priority assets. Use carryover volumes to maintain critical needs.	Water refugia and sites supporting threatened species and communities. Provide low flow and freshes in sites and reaches of priority assets. Use carryover volumes to maintain follow-up watering.	Prolong inundation/ high-flow duration at key sites and reaches of priority assets. Contribute to the full-range of in-channel flows. Use carryover to provide optimal seasonal flow patterns in subsequent years.	Increase inundation/ high-flow duration and extent across priority assets. Contribute to the full range of flows including over-bank. Use carryover to provide optimal seasonal flow patterns in subsequent years.
	Damage avoidance	*Capacity for recovery*	*Maintained health and resilience*	*Improved health and resilience*

2.1 Ecological objectives

A number of broad system-objectives exist for assets within the Lachlan catchment. These range from statutory instruments at the jurisdictional level, to overarching basin and catchment priorities.

Objectives for the use of Commonwealth environmental water (DEWHA 2009)

The *Water Act 2007* (Cwlth) prescribes that Commonwealth environmental water must be managed for the purpose of protecting or restoring environmental assets, and gives effect to relevant international agreements such as the Ramsar, Bonn, Desertification, Biodiversity and Climate Change conventions, and migratory bird agreements with Japan, China and the Republic of Korea.

The Australian Government's holdings in the Basin must be managed in accordance with the requirements of the Murray-Darling Basin Authority (MDBA) to protect and restore key environmental assets and key ecosystem functions.

These objectives are based on prevailing climatic conditions (Table 2). Climatic conditions will impact upon how much water is available in the system, including how much is available to environmental water managers. As conditions progress from extreme dry through to wet and more environmental water becomes available, the ecological objectives in Table 2 progress from damage avoidance, maintenance of refuges and the capacity for recovery, to maintaining health and resilience, and onto the expansion of a healthy ecosystem.

Murray-Darling Basin Authority objectives (MDBA 2010)

The MDBA identified the following key assets within the Lachlan catchment (MDBA 2010):

- Great Cumbung Swamp
- Booligal Wetlands
- Lachlan Swamp.

A number of proposed environmental objectives have been determined for these sites using the key environmental asset criteria. Targets to achieve these objectives have been proposed for flood-dependent vegetation communities considered essential to support wetland processes and to provide crucial habitat for identified flora and fauna (MDBA 2010).

Management targets are to:

- Booligal Wetlands:
  - provide conditions conducive to successful breeding of colonial-nesting waterbirds
  - maintain 100 per cent of the permanent and semi-permanent wetland communities in good condition
  - maintain 80 per cent of the current extent of river red gum communities in good condition
  - maintain 80 per cent of the current extent of lignum communities in good condition.
- Lachlan Swamp:
  - provide conditions conducive to successful breeding of colonial-nesting waterbirds
  - maintain 100 per cent of the permanent and semi-permanent wetland communities in good condition
  - maintain 75 per cent of the current extent of river red gum communities in good condition
  - maintain 65 per cent of the current extent of lignum communities in good condition
  - maintain 40 per cent of the current extent of black box communities in good condition.

- Great Cumbung Swamp:
  - provide conditions conducive to successful breeding of colonial-nesting waterbirds
  - maintain 95 per cent of the area of permanent and semi-permanent wetland communities in good condition
  - maintain 60 per cent of the current extent of river red gum communities in good condition
  - maintain 20 per cent of the current extent of floodplain wetland communities in good condition.

The Lachlan Catchment Action Plan (LCMA 2006)

The Catchment Action Plan, developed by the Lachlan Catchment Management Authority in 2006, addresses resource conditions of the Lachlan catchment through a number of management targets. The targets most relevant to environmental water delivery include:

- Management Target 15—By 2016, deliver 10,000 megalitres of water more efficiently for the benefit of riverine ecosystems and for identified Aboriginal cultural practices
- Management Target 20—By 2016, manage eight nationally significant wetlands and five regionally significant wetlands for improved biodiversity conservation
- Management Target 21—By 2016, implement activities identified within existing and future floodplain management plans which are identified as providing environmental benefits
- Management Target 22—By 2016, improve in-stream habitat at 80 sites.

The Lachlan Catchment Action Plan and its implementation will be reviewed during 2011. Targets relating to water management may change as they are revised as part of the development of the latest catchment action plans.

Water Sharing Plan for the Lachlan Regulated Water Source (DIPNR 2004a)

The Water Sharing Plan (WSP) has a number of objectives to ensure water management meets a variety of economic, socio-cultural and environmental needs. It can be accessed online at: http://www.austlii.edu.au/au/legis/nsw/consol_reg/wspftlrrws2003568/

The environmental objectives are to maintain or restore the key environmental features of the Lachlan River system by a river-flow regime that, as much as possible, mimics natural conditions to provide the following outcomes:

- a diversity of natural in-stream and riparian habitat and biota
- the restoration, by naturally triggered flooding, of the riverine floodplain to its previous rich mosaic of ecosystems
- the improved health and function of wetlands as the frequency and duration of inundation is restored
- an abundance and diversity of native aquatic species
- an abundance and diversity of native water birds
- the restoration of water quality that supports aquatic ecosystems
- the recovery of threatened species, communities and populations.

The WSP outlines rules for planned environmental water, including the management of 'translucent releases'. A translucent release, as defined in the WSP, is "the release from a water storage of some portion of inflow to the water storage coincident with the occurrence of that inflow" (DIPNR 2004a). Translucency flows are intended to mimic natural flows in the system and restore some natural flow characteristics (such as winter–spring flow variability), and also improve lower-system flows.

The WSP also provides for the supply of water to towns, riparian landholders, irrigation and other industry for the benefit of rural communities in the Lachlan River system. In order to meet these objectives, 'replenishment flows' are managed by State Water according to the rules outlined in the plan.

Replenishment flows, as defined in the WSP, are "flows provided to refill pools and water holes in effluent river systems downstream of the water source and provide water for household and town use and stock"(DIPNR 2004a). While this water is not strictly identified as 'environmental water' (planned environmental water or held environmental water), benefits to environmental values may accrue and improved delivery efficiency can be achieved when operational flows and environmental flows are managed in concert with each other (in this context see sections 3.1 and 5.1.6 and Tables 5 and 8).

The Draft Lachlan Environmental Water Management Plan

The Water Sharing Plan for the Lachlan Regulated River sets out rules for the allocation and release of planned environmental water. However, the Water Sharing Plan does not provide direction for the management of licences committed as adaptive environmental water or other environmental water entitlements, or the desired ecological outcomes and overall environmental objectives associated with the use of this water. The draft Lachlan Environmental Water Management Plan (LEWMP) is being developed by the Lachlan Riverine Working Group (LRWG) to address the effective use of licenced environmental water. It details:

- the wetlands of the Lachlan River and their watering needs
- the environmental watering decision-making process, e.g. wetland selection, timing, volumes and frequency
- the ecological objectives of environmental watering
- the role of the LRWG in delivering the plan
- the various rules, legislation and other institutional arrangements that must be considered.

According to its terms of reference, the role of the LRWG is to:

- identify issues relating to the allocation, accounting and management of the environmental water provisions in the Lachlan Water Sharing Plan or other allocated environmental water
- provide input to water-delivery strategies that will integrate the management of environmental flows and river operations
- review river operations and policies in relation to the management of the environmental water allowance(s)
- identify critical issues which affect the management and effectiveness of the environmental water provisions
- provide advice on other matters relevant to the sustainable management of high-value wetlands and other riverine environments that are dependent on the water sources in the Lachlan catchment
- communicate with the public and stakeholder groups through the media or other means on issues relating to environmental flows.

The draft LEWMP is a web-based tool which is constantly updated to reflect increased knowledge through monitoring and evaluation carried out by agencies including the NSW Office of Water (NOW) and the NSW Office of Environment and Heritage. Asset objectives provided by the draft LEWMP have been incorporated as relevant in the operational objectives in this document.

The Lachlan RiverBank Water Use Plan No. 1 (NSW Office of Environment and Heritage)

The Water Use Plan authorises the use of water for environmental purposes that:

- enhance opportunities for the recruitment of threatened (and other) native fish and waterbirds in the Lachlan Regulated River Water Source
- enhance river and wetland habitat for water-dependent biota in the Lachlan Regulated River Water Source
- maintain the ecological character of Murrumbidgil Swamp on Merrimajeel Creek
- restore a near-natural wetting pattern to Ita Lake
- provide for ecologically beneficial flooding of the Merrowie, Torriganny, Muggabah and Merrimajeel effluent creek systems by enhancing annual replenishment flows
- provide for ecologically beneficial flows in the Lachlan River channel below Booligal Weir; and/or contribute to maintaining the ecological character of the Great Cumbung Swamp.

3. Watering objectives for water-dependent assets

3.1 Ecological and watering objectives for asset and water management areas

There are several key considerations involved in developing asset watering requirements. Consideration has been given to each of the climate sequence scenarios in the development of environmental watering objectives for each asset or water management area (WMA). Under each climate scenario, it is likely that there will be different volumes of environmental water available, and therefore environmental watering outcomes will vary accordingly.

In reality, the climate scenarios are part of a constant continuum and only the current circumstances can be assessed in relation to the past few years to determine which scenario applies. Forecasting the future climate scenario is difficult, although short-term probabilities are provided by the Bureau of Meteorology.

Details of the water availability probabilities under each scenario, and some examples, are provided in Table 3. Under an extremely dry or dry climate, the watering of Lachlan assets using stored environmental water has limited feasibility, with only 0–47 per cent of General Security (GS) water entitlements based on modelled October allocations and 0–8 per cent of GS water entitlements based on modelled April allocations. Based on Commonwealth environmental water holdings at October 2010, there would be a maximum of 47,971 megalitres of GS water available for use under a dry climate scenario, based on modelled April allocations. This amount would be sufficient to water a limited number of assets on its own, with more watering options dependent on piggybacking opportunities.

Under a median or wet climate, the watering of a larger number of Lachlan assets would be feasible as water availability is expected to increase. The forecasted availability of Commonwealth GS water entitlements is illustrated in Table 3. Forecasts indicate that 87–100 per cent of GS allocation would be available under median-to-wet conditions under October and April allocations (Table 3). This means that between 71,957 megalitres and 82,709 megalitres of Commonwealth GS water would be available for use based on current entitlements. Probabilities of unregulated flows for various percentiles at Booligal and Willandra have also been determined. These are present for each month for extreme dry to extreme wet scenarios (Appendix 3).

From the ecological objectives for each asset/WMA, environmental watering objectives have been developed for each asset/WMA under different climate scenarios. Appendix 2 provides a description of each of these sites and relevant hydrological information in relation to the ecological values and objectives.

Flow types and how they relate to the ecological objectives are outlined in Table 4. The environmental watering objectives for each climate scenario and antecedent condition are presented in Table 5, but can be summarised as:

- avoiding damage by protecting the asset from over-grazing and weeds and reduce the duration of time between flow events
- providing for a natural drying cycle
- providing drought refuge for native fish species and waterbirds
- supporting wetland vegetation and waterbird breeding
- improving hydrologic connectivity between channel and floodplain
- increasing hydrological variability through increased flow volumes in floods and freshes.

The volume-to-fill estimates in Table 5 for wetland sites are based on the area of the site and an upper limit watering requirement of 12 megalitres per hectare (see also section 5.1.6), or according to other advice as outlined in Table 5. The environmental watering objectives (Table 5) are subsequently used to develop the corresponding environmental water order in Table 8.

It is important to note that in some cases the environmental watering objective may be met by baseflows or replenishment flows (e.g. see Table 4), but these flows are not intended to be met by held environmental water releases. However if the base or replenishment flow is not provided, additional water may need to be provided from held environmental water to meet the watering objective and order (see also section 5.1.6 and Table 8).

Table 3: Likely modelled volume available to the environment from Commonwealth environmental water holdings (as at October 2010) and NSW Riverbank entitlements.

			October allocation				April allocation			
Holder	Licence volume	Entitlement category	Extreme dry	Dry	Median	Wet	Extreme dry	Dry	Median	Wet
General-security access licence allocation (%)			0	47	87	100	0	58	100	100
High-security access licence allocation (%)			100	100	100	100	100	100	100	100
Commonwealth environmental water (ML)	733	High	733	733	733	733	733	733	733	733
NSW Riverbank (ML)	1,000	High	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000
Commonwealth environmental water (ML)	82,709	General	0	38,873	71,957	82,709	0	47,971	82,709	82,709
NSW Riverbank (ML)	24,575	General	0	11,550	21,380	24,575	0	14,254	24,575	24,575
Commonwealth environmental water (Lake Brewster Water Savings) (ML)	12,000	General	0	5,640	10,440	12,000	0	6,960	12,000	12,000

(Note: does not include environmental water under the Water Sharing Plan).

Table 4: Flow types and relationship to asset ecological objectives

Flow type	Water management area	Asset ecological objectives
Baseflow—to provide sufficient baseflow to maintain suitable water quality in the regulated river channel during drought years.	Permanent regulated river section.	Maintain water quality within channels and pools. Prevent stratification in deep pools.
		Promote productivity to maintain food webs and ecosystem function for in-channel flora and fauna.
Provide a drought refuge for native fish species; avoid the build-up of organic matter and maintain riparian and in-stream vegetation health.		Prevent fish stranding and allow biota to complete flow-driven critical life cycle processes such as spawning, seed setting and dormant stages.
		Maintain inundation of weir pools in the river to prevent exposure of acid sulphate soils, e.g. Booligal Weir pool.
Minor Inflows—Increase hydrological variability through increased flow volumes in floods and freshes. Flood smaller wetlands with low commence-to-fill (CTF).	Small-to-medium-sized wetlands with low CTF or structures for water delivery, e.g. Burrawang West Lagoon, Yarnel Lagoon, Lake Brewster Inflow Wetland.	Protect wetland habitat for native fish (including olive perchlet and purple spotted gudgeon), frogs and waterbirds (including brolgas).
		Establish and maintain native water plants for improved water quality and wetland habitat outcomes.
		Promote diversity outcomes through flooding lagoons and associated riverine areas.
Medium Inflows—Increase extent and duration of inundation and connectivity; support colonial waterbirds and fish.	End-of-system flows; distributary systems and associated wetlands, e.g. Willandra Creek, upper Merrowie Creek, Muggabah and Merrimajeel Creeks.	Provide adequate flooding regime to support river red gum, black box and lignum communities associated with distributary systems.
		Provide nesting and foraging habitat for waterbirds such as ibis, freckled duck, blue-billed duck, egrets, herons.
		Provide adequate water depth and flood frequency to support Cumbung reed bed.
		Increase connectivity between floodplain and distributary creeks to increase productivity.
High Inflows—Increase extent and duration of inundation and connectivity; support colonial waterbirds and fish; increase open water areas.	Inundate wetlands requiring greater volumes and high CTF, Cumbung Swamp red gum forest, Tarwong Lake, Lake Merrimajeel and Lake Ita.	Provide adequate flooding regime to support river red gum, black box and lignum communities associated with distributary systems.
		Maintain open water areas by providing adequate flooding flows to lakes.
		Increase duration of connectivity between floodplain and distributary creeks to increase productivity.
		Provide nesting and foraging habitat for waterbirds such as ibis, freckled duck, blue-billed duck, egrets, herons.

Table 5: Environmental watering objectives to meet ecological objectives under different climate scenarios.

Asset	WMA	Climate scenario	Asset ecological objectives[1]	Asset environmental watering objectives[2,3]
Lachlan River channel	Lachlan River reach-Wyangala-Jemalong	Extreme dry	Provide drought refuge for native fish species in pools.	Baseflow to prevent cease-to-flow.
		Dry	Provide drought refuge for native fish species in pools.	Baseflow to prevent cease-to-flow.
		Median	Provide habitat for native fish species in pools and connectivity to other reaches.	Drownout Cottons Weir (Forbes) for 1 week.
		Wet	Provide habitat for native fish species in pools and connectivity to other reaches.	Drownout Cottons Weir (Forbes) for 2 weeks.
	Lachlan River reach-Jemalong- Lake Cargelligo	Extreme dry	Provide drought refuge for olive perchlet and other native fish species in pools.	Baseflow to prevent cease-to-flow.
		Dry	Provide drought refuge for olive perchlet and other native fish species in pools.	Baseflow to prevent cease-to-flow.
		Median	Provide habitat for native fish species in pools and connectivity to other reaches.	Drownout Condobolin and West Condobolin Weirs for 1 week.
		Wet	Provide habitat for native fish species in pools and connectivity to other reaches.	Drownout Condobolin and West Condobolin Weirs for 2 weeks.
	Lachlan River reach-Lake Cargelligo-Lake Brewster	Extreme dry	Brewster weir pool—provide drought refuge for olive perchlet and other native fish species.	Baseflow to prevent cease-to-flow.
		Dry	Brewster weir pool—provide drought refuge for olive perchlet and other native fish species.	Baseflow to prevent cease-to-flow.
		Median	Brewster weir pool—improve habitat for olive perchlet and other native fish species.	Maintain inundation of Brewster Weir pool.
		Wet	Brewster weir pool—improve habitat for olive perchlet and other native fish species.	Maintain inundation of Brewster Weir pool.
	Lachlan River reach-Lake Brewster-Great Cumbung Swamp	Extreme dry	Provide drought refuge for native fish species in pools.	Baseflow to prevent cease-to-flow.
		Dry	Provide drought refuge for native fish species in pools.	Baseflow to prevent cease-to-flow.
		Median	Provide habitat for native fish species in pools and connectivity to other reaches.	Drownout Willandra (8,500 ML/d) and Hillston (4,750 ML/d) Weirs for 1 week.
		Wet	Provide habitat for native fish species in pools and connectivity to other reaches.	Drownout Willandra (8,500 ML/d) and Hillston (4,750 ML/d) Weirs for 2 weeks.

1 Ecological objectives may change as water is accrued for each climate scenario as per Table 3

2 The baseflows and water for consumptive use (e.g. replenishment flows) are not to be substituted by held environmental water. In instances when these flows are not provided, additional water may need to be provided from held environmental water to meet the watering objectives. In some systems this may not be feasible given the volume that would be required.

3 Appendix 2 provides the necessary narrative for the development of these objectives.

Asset	WMA	Climate scenario	Asset ecological objectives[1]	Asset environmental watering objectives[23]
Burrawang West Lagoon	Burrawang West Lagoon	Extreme dry	Protect relocated purple-spotted gudgeons (if viable population still exists), other native fish and brolga habitat.	Deliver up to 50 ML (volume-to-fill) to Burrawang West Lagoon.
		Dry	Protect relocated purple-spotted gudgeons (if viable population still exists), other native fish and brolga habitat.	Deliver up to 50 ML (volume-to-fill) to Burrawang West Lagoon.
		Median	Support breeding opportunities for relocated purple-spotted gudgeons (if viable population still exists), other native fish and frogs and protect brolga habitat.	Deliver up to 50 ML (volume-to-fill) to Burrawang West Lagoon.
		Wet	Support breeding opportunities for relocated purple-spotted gudgeons (if viable population still exists), other native fish and frogs and protect brolga habitat. Water riparian vegetation and provide connectivity to floodplain.	Deliver >50 ML (volume-to-fill) to Burrawang West Lagoon.
Yarnel Lagoon	Yarnel Lagoon	Extreme dry	Protect frog and brolga habitat.	Deliver up to 360 ML (volume-to-fill) to Yarnel Lagoon
		Dry	Protect frog and brolga habitat.	Deliver up to 360 ML (volume-to-fill) to Yarnel Lagoon
		Median	Water riparian vegetation, support frog and brolga breeding.	Deliver up to 360 ML (volume-to-fill) to Yarnel Lagoon
		Wet	Support riparian vegetation, frog and brolga breeding. Provide connectivity to floodplain.	Deliver >360 ML (volume-to-fill) to Yarnel Lagoon
Booberoi Creek	Booberoi Creek	Extreme dry	Provide native fish and water plant refuge.	Baseflow to maintain pools.
		Dry	Provide native fish and water plant refuge.	Baseflow to maintain pools.
		Median	Support native fish passage and recruitment.	Deliver flushing flows to Booberoi Creek up to 3,000 ML.
		Wet	Support native fish passage and recruitment.	Deliver flushing flows to Booberoi Creek up to 3,000 ML.

Asset	WMA	Climate scenario	Asset ecological objectives[1]	Asset environmental watering objectives[23]
Lake Brewster	Lake Brewster Inflow Wetland	Extreme dry	Provide natural drying cycle.	No water delivered under extremely dry conditions.
		Dry	Support wetland plant growth and pelican breeding, provide improved habitat for olive perchlet and other wetland species.	Deliver up to 1,500 ML (volume-to-fill) to Brewster Inflow Wetland. (Note: this estimate provided by State Water.)
		Median	Support wetland plant growth and pelican breeding, provide improved habitat for olive perchlet and other wetland species.	Deliver up to 1,500 ML (volume-to-fill) to Brewster Inflow Wetland. (Note: this estimate provided by State Water.)
		Wet	Support wetland plant growth and pelican breeding, provide improved habitat for olive perchlet and other wetland species.	Deliver up to 1,500 ML (volume-to-fill) to Brewster Inflow Wetland. (Note: this estimate provided by State Water.)
	Lake Brewster Outflow Wetland	Extreme dry	No water delivered under extremely dry conditions.	No water delivered under extremely dry conditions.
		Dry	Establish/maintain wetland vegetation for improved water quality in cells 1, 2 and 3.	Deliver up to 5,000 ML (volume-to-fill) to Brewster Outflow Wetland. (Note: this estimate provided by State Water.)
		Median	Establish/maintain wetland vegetation for improved water quality in cells 1, 2 and 3.	Deliver up to 5,000 ML (volume-to-fill) to Brewster Outflow Wetland. (Note: this estimate provided by State Water.)
		Wet	Establish/maintain wetland vegetation for improved water quality in cells 1, 2 and 3 plus the additional northern wetland cell.	Deliver >5,000 ML to Brewster Outflow Wetland. Volume-to-fill of the northern cell not known.

Asset	WMA	Climate scenario	Asset ecological objectives[1]	Asset environmental watering objectives[23]
Willandra Creek	Willandra Creek- upstream reach (Willandra Regulator to Willandra Homestead Weir)	Extreme dry	Provide drought refuge for native fish and waterbirds, particularly with regard to Willandra National Park riparian areas and Homestead Weir pool.	Base flows to wet channel and fill pools.
		Dry	Provide drought refuge for native fish and waterbirds, particularly with regard to Willandra National Park riparian areas and Homestead Weir pool.	Base flows to wet channel and fill pools.
		Median	Support waterbird breeding, particularly within Willandra National Park riparian areas and Homestead Weir pool. Increase connectivity through weir drownouts.	Volume of environmental water required to achieve the asset ecological objective is currently unknowwn.
		Wet	As above.	Volume of environmental water required to achieve the asset ecological objective is currently unknown.
	Willandra Creek- downstream reach (Homestead Weir to Ivanhoe/Balranald Road)	Extreme dry	Provide drought refuge for native fish and waterbirds.	Baseflows to wet channel and fill pools.
		Dry	Provide drought refuge for native fish and waterbirds.	Baseflows to wet channel and fill pools.
		Median	Maintain wetland habitats for native fish and waterbirds. Increase connectivity through weir drownouts.	Volume of environmental water required to achieve the asset ecological objective is currently unknown.
		Wet	Maintain wetland habitats for native fish and waterbirds. Increase connectivity through weir drownouts.	Volume of environmental water required to achieve the asset ecological objective is currently unknown.
	Morrisons Lake	Extreme dry	Provide natural drying cycle.	No water delivered under extremely dry conditions.
		Dry	Provide natural drying cycle.	No water delivered under dry conditions.
		Median	Support wetland habitat and waterbirds.	Deliver up to 4,000 ML (volume-to-fill) to Morrisons Lake. (Note: this estimate provided by State Water.)
		Wet	Support wetland habitat and waterbirds.	Deliver up to 4,000 ML (volume-to-fill) to Morrisons Lake. (Note: this estimate provided by State Water.)

Asset	WMA	Climate scenario	Asset ecological objectives[1]	Asset environmental watering objectives[23]
Merrowie Creek	Upper Merrowie Creek (offtake to Toms Lake)	Extreme dry	Provide drought refuge for native fish and waterbirds, and provide connectivity.	Baseflows to wet channel and fill pools.
		Dry	Support creek channel vegetation (red gum, black box, lignum) for native fish and waterbirds, and provide connectivity.	Baseflows to wet channel and fill pools.
		Median	Support creek channel vegetation (red gum, black box, lignum) for native fish and waterbirds, and provide connectivity.	Baseflows to wet channel and fill pools.
		Wet	Support creek channel vegetation (red gum, black box, lignum) for native fish and waterbirds, and provide connectivity.	Baseflows to wet channel and fill pools.
	Merrowie Creek- Toms Lake	Extreme dry	Provide drought refuge for native fish and waterbirds and provide connectivity.	Baseflows to wet channel and fill pools.
		Dry	Support wetland habitats (red gum, black box, lignum) for native fish and waterbirds and provide connectivity.	Deliver 3,000–3,600 ML.
		Median	Support wetland habitats (red gum, black box, lignum) for native fish and waterbirds and provide connectivity.	Deliver 3,000–5,000 ML.
		Wet	Support wetland habitats for native fish and colonial bird breeding.	Deliver 5,000–7,200 ML.
	Merrowie Creek- Mutherumbung Weir pool	Extreme dry	Provide drought refuge for native fish and waterbirds, and provide connectivity.	Baseflows to wet channel and fill pools.
		Dry	Support wetland habitats (red gum, black box, lignum) for native fish and waterbirds, and provide connectivity.	Deliver 3,500–5,000 ML to Mutherumbung Weir.
		Median	Support red gums, black box, lignum and bird breeding in the lake and swamps.	Deliver 3,500–5,000 ML to Mutherumbung Weir.
		Wet	Support wetland habitats for native fish and colonial bird breeding.	Deliver 5,000–7,200 ML to Mutherumbung Weir.
	Merrowie Creek- Cuba Dam	Extreme dry	Provide drought refuge for native fish and waterbirds and provide connectivity.	Baseflows to wet channel and fill pools.
		Dry	Support wetland habitats (red gum, black box, lignum) for native fish and waterbirds and provide connectivity.	Deliver up to 5,000 ML to Cuba Dam.
		Median	Improve the condition of river red gum, black box and lignum communities and support bird breeding in the lake and swamps.	Deliver up to 5,000 ML to Cuba Dam.
		Wet	Support wetland habitats for native fish and colonial bird breeding.	Deliver up to 7,200 ML to Cuba Dam.
	Merrowie Creek- Lake Tarwong and Tarwong Swamps	Extreme dry	Provide natural drying cycle.	No water delivered under extremely dry conditions.
		Dry	Provide natural drying cycle.	No water delivered under dry conditions.
		Median	Improve the condition of river red gum communities and support bird breeding in the lake.	Deliver up to 2,000 ML to Lake Tarwong.
		Wet	Improve the condition of river red gum, black box and lignum conditions and support waterbird breeding in the lake and swamps.	Deliver up to 9,000 ML to Lake Tarwong and the south and north swamps.

Asset	WMA	Climate scenario	Asset ecological objectives[1]	Asset environmental watering objectives[23]
Moon Moon Swamp	Moon Moon Swamp	Extreme dry	Provide natural drying cycle.	No water delivered under extremely dry conditions.
		Dry	Provide natural drying cycle.	No water delivered under dry conditions.
		Median	Provide water to river red gums and drought refuge for waterbirds.	Deliver up to 2,500 ML to Moon Moon Swamp (this is a nominal requirement as the volume of water required for breeding is unknown).
		Wet	Extend duration of river red gum watering and support waterbird breeding. Floodplain inundation downstream of Moon Moon Swamp which is an area of 20,000–30,000 ha.	Deliver up to 2,500 ML to Moon Moon Swamp (as above) and downstream environment.
Booligal Wetland	Booligal Swamp	Extreme dry	Provide natural drying cycle. (Replenishment flow will water habitat along Merrimajeel Creek.)	Baseflows to wet channel and fill pools.
		Dry	Provide natural drying cycle. (Replenishment flow will water habitat along Merrimajeel Creek.)	Baseflows to wet channel and fill pools.
		Median	Improve lignum condition and support waterbird breeding events.	Deliver up to 5,000 ML to Booligal Swamp.
		Wet	Support lignum condition and support waterbird-breeding events.	Deliver up to 5,000 ML to Booligal Swamp.
	Murrumbidgil Swamp	Extreme dry	Provide natural drying cycle. Replenishment flow will water habitat along Merrimajeel Creek.	No water delivered under extremely dry conditions.
		Dry	Provide water to river red gums.	Deliver 1,400 ML (volume-to-fill) to Murrumbidgil Swamp.
		Median	Provide water to river red gums and support bird breeding.	Deliver >1,400 ML (volume-to-fill) to Murrumbidgil Swamp. The volume required to support bird breeding is unknown.
		Wet	Provide water to river red gums and bird breeding.	Deliver >1,400 ML (volume-to-fill) to Murrumbidgil Swamp. The volume required to support bird breeding is unknown.
	Lake Merrimajeel	Extreme dry	Provide natural drying cycle. (Replenishment flow will water habitat along Merrimajeel Creek.)	No water delivered under extremely dry conditions.
		Dry	Provide natural drying cycle. (Replenishment flow will water habitat along Merrimajeel Creek.)	No water delivered under dry conditions.
		Median	Provide water for wetland habitat.	Deliver 1,200 ML (volume-to-fill) to Lake Merrimajeel.
		Wet	Providing water for wetland habitat and support waterbird breeding.	Deliver >1,200 ML (volume-to-fill) to Lake Merrimajeel. The volume required to support bird breeding is unknown.
	Lower Gum Swamp	Extreme dry	Provide natural drying cycle. Replenishment flow will water habitat along Merrimajeel Creek.	No water delivered under extremely dry conditions.
		Dry	Provide natural drying cycle. Replenishment flow will water habitat along Merrimajeel Creek.	No water delivered under dry conditions.
		Median	Improve the condition of river red gum communities.	Deliver up to 3,400 ML (volume-to-fill) to Lower Gum Swamp.
		Wet	Improve the condition of river red gum communities and support water bird breeding.	Deliver up to 2,500 ML to Lower Gum Swamp. This volume based on Booligal swamp experience.

Asset	WMA	Climate scenario	Asset ecological objectives[1]	Asset environmental watering objectives[23]
Lachlan Swamps	Lake Waljeers	Extreme dry	Provide natural drying cycle.	No water delivered under extremely dry conditions.
		Dry	Provide water to river red gum communities.	Deliver up to 2,600 ML (volume-to-fill) to Lake Waljeers.
		Median	Provide water to river red gum communities.	Deliver up to 6,240 ML to Lake Waljeers.
		Wet	Provide water to river red gum communities.	Deliver up to 6,240 ML to Lake Waljeers.
	Peppermint Swamp	Extreme dry	Provide natural drying cycle.	No water delivered under extremely dry conditions.
		Dry	Provide water to river red gum communities.	Deliver up to 1,440 ML to Peppermint Swamp
		Median	Provide water to river red gum communities and support bird breeding.	Deliver >1,440 ML to Peppermint Swamp. The volume of water to support waterbird breeding is not known.
		Wet	Provide water to river red gum communities and support waterbird breeding.	Deliver >1,440 ML to Peppermint Swamp. The volume of water to support waterbird breeding is not known.
Ita Lake	Ita Lake	Extreme dry	Provide natural drying cycle.	No water delivered under extremely dry conditions.
		Dry	Support waterbird and native fish habitat within the Kalyarr Conservation Area.	Deliver up to 14,400 ML to Ita Lake.
		Median	Provide waterbird and native fish habitat within the Kalyarr Conservation Area.	Deliver up to 14,400 ML to Ita Lake.
		Wet	Provide water to river red gum and black box communities within the Kalyarr Conservation Area.	Deliver >14,400 ML to Ita Lake.
Baconian Swamp	Baconian Swamp	Extreme dry	Provide natural drying cycle.	No water delivered under extremely dry conditions.
		Dry	Provide water to river red gum communities.	Deliver 9,600 ML to Baconian Swamp
		Median	Improve the condition of river red gum and black box communities and support waterbird and frog breeding.	Deliver >9,600 ML to Baconian Swamp. Volumes required for waterbird and frog breeding unknown.
		Wet	Improve the condition of river red gum and black box communities and support bird and frog breeding.	Deliver >9,600 ML to Baconian Swamp. Volumes required for waterbird and frog breeding unknown.

Asset	WMA	Climate scenario	Asset ecological objectives[1]	Asset environmental watering objectives[23]
Great Cumbung Swamp (GCS)	Reed bed	Extreme dry	Provide natural drying cycle.	No water delivered under extremely dry conditions.
		Dry	Maintain reed bed condition.	Deliver up to 4,900 ML to reed bed.
		Median	Maintain reed bed condition.	Deliver up to 4,900 ML to reed bed.
		Wet	Maintain and improve reed bed condition.	Deliver up to 4,900 ML to reed bed.
	GCS WMA	Extreme dry	Provide natural drying cycle.	No water delivered under extremely dry conditions
		Dry	Provide natural drying cycle.	No water delivered under dry conditions.
		Median	Improve the condition of river red gum communities.	Deliver up to 30,000 ML to GCS.
		Wet	Improve the condition of river red gum and black box communities and support bird breeding.	Deliver up to 45,000 ML to GCS.

PART 2:
Water use strategy

4. Environmental water requirements

4.1 Watering requirements

Asset environmental watering objectives were presented in the previous section. The associated watering requirements and delivery regimes for these objectives are presented in this section. Watering requirements for wetland-dependent vegetation and ecological components have been documented in a number of reports including Roberts and Marston (2000), Davis et al. (2001), and Rogers and Ralph (2010). The survival and maintenance watering requirements of the major ecological components found in many lower-Lachlan wetlands are outlined in Table 6, based on information provided by Rogers and Ralph (2010). Fish-specific requirements have been extracted from Lintermans (2007). While the list in Table 6 is not exhaustive, it provides detailed watering information on a number of important features associated with Lachlan assets.

These watering requirements have been used to determine appropriate watering regimes for Lachlan assets (section 5 and Table 8). The dominant vegetation or ecological component within each wetland has been used as the basis of watering requirements for each wetland. Table 5 (in section 3) summarises the ecological objectives for watering purposes of each wetland.

Table 6: Watering requirements for selected water-dependent species of the Lachlan River (modified from Rogers & Ralph 2010; Lintermans 2007)

Water-dependent component	Ideal frequency	Ideal duration	Max duration	Ideal timing	Max timing	Ideal depth	Max depth	Ideal dry spell	Max dry spell
Plants survival and maintenance									
River red gum	1–3 yrs	2–8 mths	24 mths	Winter– spring	Winter–early summer	–	–	5–15 mths	36–48 mths
Black box	1 in 2–5 yrs	2–4 mths	5 mths	Any	Any	–	–	Variable	Unknown
Lignum	3–10 yrs	1–6 mths	12 mths	Spring–early summer	–	0–60 cm	–	1–10 yrs	Unknown
Common reed	1–2 yrs	~6 mths	12 mths or permanent	Spring	Any	20–50 cm	2 m	Few mths	12 mths
Waterbird breeding									
Great and intermediate egret	Not known	12 mths 3–4 mths breeding	–	Nov–May	Sept–May	Deep–slow fall	–	Not listed	Not listed
Little egret	Not known	6 mths 3–4 mths breeding	–	Oct–March	–	Deep–mod fall	–	Not listed	Not listed
Straw-necked ibis	Not known	9–12 mths 3-mths breeding	–	Sept–Feb	Anytime	0.5–1 m slow fall	–	Not listed	Not listed
Glossy ibis	Not known	2-mths breeding	–	Oct–Feb		Deep–slow fall	–	Not listed	Not listed
Grey teal	Not known	4–5 mths 3–4 mths breeding	–	June–Feb	Anytime	Unknown–mod fall	–	Not listed	Not listed
Freckled duck	Not known	5 mths 3-mths breeding	–	June–Dec	Anytime	Unknown mod–slow fall	–	Not listed	Not listed
Brolga	Not known	3–4 mths		July–Nov	May–March	0.24– 0.72 m	–	Not listed	Not listed

Water-dependent component	Ideal frequency	Ideal duration	Max duration	Ideal timing	Max timing	Ideal depth	Max depth	Ideal dry spell	Max dry spell
Native fish									
Olive perchlet	Not listed	Not listed	Not listed	Oct–Dec	Not listed	Not listed	Not listed	Not listed	Not listed
Purple spotted gudgeon	Not listed	Not listed	Not listed	Oct–April	Not listed	Not listed	Not listed	Not listed	Not listed
Murray cod	Not listed	Not listed	Not listed	Sept–Dec	Not listed	Not listed	Not listed	Not listed	Not listed
Macquarie perch	Not listed	Not listed	Not listed	Oct–Dec	Not listed	Not listed	Not listed	Not listed	Not listed
Golden perch	Not listed	Not listed	Not listed	Oct–Dec	Not listed	Not listed	Not listed	Not listed	Not listed
Silver perch	Not listed	Not listed	Not listed	Sept–Mar	Not listed	Not listed	Not listed	Not listed	Not listed
Freshwater catfish	Not listed	Not listed	Not listed	Oct–Jan	Not listed	Not listed	Not listed	Not listed	Not listed
Southern pygmy perch	Not listed	Not listed	Not listed	Sept–Jan	Not listed	Not listed	Not listed	Not listed	Not listed
Unspecked hardyhead	Not listed	Not listed	Not listed	Oct–Feb	Not listed	Not listed	Not listed	Not listed	Not listed
Northern river blackfish	Not listed	Not listed	Not listed	Oct–Jan	Not listed	Not listed	Not listed	Not listed	Not listed
Frogs									

Water-dependent component	Ideal frequency	Ideal duration	Max duration	Ideal timing	Max timing	Ideal depth	Max depth	Ideal dry spell	Max dry spell
Eastern froglet	<3 mths—permanent	Not listed	2–4 mths	Summer–autumn	Not listed	Not listed	Not listed	Not listed	Not listed
Perons tree frog	<3 mths—permanent	Not listed	3–4 mths	Summer	Not listed	Not listed	Not listed	Not listed	Not listed
Southern bell frog	3 mths—permanent	Not listed	3–5 mths	Summer	Not listed	Not listed	Not listed	Not listed	Not listed

Note: Rogers and Ralph (2010) also provides additional information on other outcomes such as reproduction and regeneration requirements and a functional classification for floodplain plants.

5. Operating regimes and environmental water-delivery strategies

To meet environmental watering objectives for an asset requires the delivery of flows at an appropriate volume and duration that meets the needs of the ecological objective. For the successful implementation of a delivery strategy, there are many matters that need to be considered for environmental water delivery in terms of determining the requirements of the 'water order'. The combination of these factors forms the operational delivery regime. The main considerations for water orders for assets on the Lachlan are provided below.

As identified in section 1.3, the existence of the two re-regulating storages of Lake Cargelligo and Lake Brewster has major implications for the operation of the Lachlan River. When water is stored in Lake Brewster the river operates as two rivers, Wyangala to Brewster Weir and then Brewster Weir to Oxley. When Lake Brewster is empty, the river is operated from Wyangala Dam.

As the river operator, State Water addresses these considerations and determines the delivery requirements to meet environmental water orders required by environmental water managers. Section 5.2 and Table 8 provide the water orders for each asset/WMA.

5.1 Delivery considerations

5.1.1 Travel time for delivery of environmental water

The length of time it takes for environmental water to reach a targeted asset from the water storage is an important consideration, particularly in the Lachlan, given the multiple storages and the length of the river and distributary creek channels. The following are approximate travel times:

- Wyangala to Lake Cargelligo—15 days
- Lake Cargelligo to Lake Brewster—three to five days
- Lake Brewster to Moon Moon Swamp—17 days
- Lake Brewster to Booligal Weir—20 days
- Booligal Weir to Corrong—18 days
- Corrong to Oxley—7 to 14 days depending on flow level.

The total travel time from Wyangala to Oxley is approximately 90 days.

Additional travel times are required along the distributary/effluent creek systems (see asset profiles for more details):

- Willandra Creek—approximately 90 days to Morrison's Lake and 100 days to Balranald/Ivanhoe Road
- Merrowie Creek—approximately 50–60 days to Cuba Dam
- Merrimajeel Creek—approximately 70 days to Murrumbidgil Swamp.

Stock and domestic replenishment flows are frequently delivered to the lower Lachlan, including to its distributaries, and delivered annually if water is available. As much as possible these replenishment flows are provided by unregulated tributary flows, but if these flows do not occur, replenishment flows can be provided from the river regulation storages. In the latter circumstances and for the lower river areas, it is preferable to provide these flows from Lake Cargelligo and/or Lake Brewster. Section 10.2 provides more details on these replenishment flows as there is potential to use this water in conjunction with environmental water releases.

5.1.2 Storage release capacities

The following storage release capacities apply to each storage at maximum storage levels (DLWC 2002). The release capacity will decrease as the storage level drops. Any order for environmental water needs to consider other water orders and therefore possible valve and channel (see section 5.3) capacity sharing:

- The outlet valves at Wyangala Dam have a maximum capacity of 7,400 ML/d at maximum storage level.
- When the Wyangala storage exceeds 55 per cent it is possible to release water via the spillway gates as per the following (the operation of these gates is more complex and there will be less precision with the release volumes than via the dam outlet valves):
  - at 57 per cent storage, releases of up to 10,000 ML/d
  - at 58 per cent storage, releases up to 20,000 ML/d[2]
  - at 62 per cent storage, releases up to 70,000 ML/d.
- Lake Cargelligo has an outlet capacity of 1,000 ML/d when full.
- Lake Brewster, in conjunction with the conduit for Brewster Weir, previously had a release capacity of 3,500 ML/d. The current arrangements for releases are 1,200–3,000 ML/d as per the following:
  - 1,200 ML/d via Brewster Weir conduit
  - 600–1,800 ML/d via the lake depending on storage capacity.

5.1.3 Channel capacities

The main parts of the Lachlan River which have channel capacity limitations for regulated water-delivery purposes are:

- Forbes—channel capacity is about 32,500 ML/d. This is not a barrier to regulated releases, though some minor innundation is experienced at 15,000 ML/d in this area.
- Condobolin—channel capacity is about 6,000 ML/d.
- Condobolin anabranches—flows are generally delivered at around 1,000 ML/d at Condobolin. When discharge exceeds approximately 4,000ML/d in Island Creek upstream of Condobolin, water may start to spill out of the anabranch system, and onto the floodplain and other creeks. Other Condobolin anabranches have much lower channel constraints with the Goobang/Bumbuggan system limited to 2,000 ML/d, Wallamundry system less than 390 ML/d and Booberoi Creek less than 175 ML/d (S. Sritharan, State Water, pers. comm.). This area would be particularly sensitive to overbank flows since there is considerable cropping undertaken adjacent to these Creeks.

2 Flows above about 15,000 ML/d at Forbes start to break out of the river channel and flood private lands. Releases from Wyangala above this rate are only undertaken for flood-mitigation purposes. Therefore total Wyangala releases above 15,000 ML/d are avoided under the current translucent environmental releases under the Water Sharing Plan.

- Willandra Creek—regulator is overtopped by flows of 2,400 ML/d, with substantial flows passing down Willandra Creek as this threshold is further exceeded (Note: the natural commence-to-flow for Willandra Creek was around 8,000 ML/d—see Willandra asset profile.)
- Middle Creek—commence-to-flow is 2,000 ML/d at Hillston Weir.
- Merrowie Creek—commence-to-flow (assuming no boards and the Gonowlia Weir Regulator is open) is 1,500 ML/d at Hillston Weir.
- Lake Waljeers area—overbank flows into this system commence at around 800–1,200 ML/d at Booligal Weir. Lake Ita, which is located in this area, appears to have a commence-to-flow of around 600 ML/d at Corrong following the removal of a regulator from its inlet channel. This figure is yet to be confirmed.

Channel capacity has to be shared with other water uses and users and exceeding channel capacity may result in flooding of cultivated land (mainly in the Condobolin area) or other non-target areas. Channel constraints, where known, have generally been taken into account in the delivery of environmental water. But these conditions, particularly for lower capacity channels, may change with obstructions which may appear in these channels, for example due to vegetation growth from plants like Cumbungi.

Consequently, third party impacts from environmental water delivery must be considered when water orders are placed to reduce the risk to property and infrastructure.

5.1.4 Availability of conveyance water

Conveyance water is that which is provided to 'run the river' and provide for the natural water forfeit which occurs along the river and creek channels due to "water evaporation and seepage from surface water sources and man-made water transportation features, such as irrigation channels" (National Water Commission 2011). On most parts of regulated rivers, water orders for extractive or environmental use (orders) are provided 'on top of' the conveyance water. In NSW, volume requirements to provide for conveyance water are shared amongst all users and accounted for when the annual and progressive water resource assessment is undertaken by the NSW Office of Water in conjunction with State Water. This volumetric requirement is set aside in the relevant water storages prior to any other water allocations (both high and general security) being determined. In 2003 the annual conveyance reserve volume in the Lachlan was about 200,000 megalitres in Wyangala Dam (LRMC 2003). However this reserve may have altered, and possibly reduced, in recent years with the experience gained in running the river more efficiently during the recent drought (see also section 8.2).

Locations along the river and creeks to which conveyance water is provided is an important consideration for an environmental water manager. If an environmental water order is placed within the conveyance system limits, the order only needs to consider the asset watering needs. However, if the asset is outside of the conveyance system limits, the environmental water order will need to provide for any conveyance water losses. The current NSW RiverBank Water Use Plan No. 1 specifies these locations (see also section 6.2) according to the following arrangements:

"Part 3 Plan area

This plan authorises the use of water within:

(1) those sections of the Lachlan Regulated River Water Source that are downstream of Wyangala Dam;

(2) the Merrowie Creek Trust District;

(3) the Torriganny, Muggabah and Merrimajeel Creeks Trust District;

(4) the following specific areas prioritised by RiverBank for water application, being:

(a) the lagoon on the property "Burrawang West" formed behind a structure on Goobang Creek (Grid Reference 542100 east, 6331700 north, Condobolin Map 1:50,000, Sheet 8331);

(b) the lagoon on the property "Yarnel" formed behind a structure on Wallaroi Creek (Grid Reference 505500 east, 6327500 north, Condobolin Map 1:50,000, Sheet 8331);

(c) Murrumbidgil Swamp (Grid Reference 281000 east, 6249000 north, Tarwong Map 1:50,000, Sheet 7730) on Merrimajeel Creek;

(d) Lake Ita (Grid Reference 252000 east, 6203000 north, Maude Map 1:50,000, Sheet 7729) on Kalyarr State Conservation Area;

(e) The Lachlan River channel and associated riparian lands below Booligal Weir; and

(f) The Great Cumbung Swamp (Grid Reference 230000 east, 6206000 north, Maude Map 1:50,000, Sheet 7729).

Part 5 Conditions on water use

4) For the purpose of measurement of water delivered, the access licences that nominate the plan shall also nominate the works owned by State Water in order to use water allocations and for water accounting.

1. Access licences that order water for use:

a. Under Part 3 (1) shall nominate Brewster Weir;

b. Under Part 3 (2) shall nominate Merrowie Offtake Regulator;

c. Under Part 3 (3) and (4)(c) shall nominate Torriganny Weir;

d. Under Part 3 (3) and (4)(c) shall nominate Merrimajeel Offtake Regulator (to be constructed);

e. Under Part 3 (3) and (4)(c) shall nominate Muggabah Offtake Regulator (to be constructed); and

f. Under Part 3 (4)(e) and (f) shall nominate Booligal Weir."

Generally, conveyance water is available for the watering of some river-based environmental assets upstream of Booligal Weir, but not downstream. This consideration is further addressed in section 5.2 below.

Given some environmental water orders will likely result in the need for more conveyance water (e.g. Moon Moon Lake—see below), this could result in more water needing to be set aside in the resource assessment process. If this occurs, it will reduce the volumes and reliability of general-security allocations.

5.1.5 Base conveyance flows in the regulated river channel

The baseflow provided to the river channel varies with the time of the year and in consideration of groundwater accessions and losses in the relevant river section. For the river upstream of Lake Cargelligo the seasonal baseflow requirement is lower in the winter period (as low as 100 ML/d; see Appendix 6) and much higher during the summer (up to 400–500 ML/d; see Appendix 6) with greater evapotranspiration. Baseflow requirements for the river downstream of Lake Cargelligo are also provided in Appendix 6. Because of this variability, the baseflows for the river sections in Table 7 are only for the minimum requirement.

In severe drought periods, the commitment is to provide town water supply flows only as far as Condobolin. Consequently, under extreme circumstances, some sections of the river downstream of this point may not receive regulated baseflow releases.

5.1.6 Piggybacking opportunities

The existence of conveyance water in parts of the Lachlan provides for piggybacking opportunities to assist efficient delivery of environmental water orders. Other water in the river also provides opportunities for piggybacking, including stock and domestic replenishments, other water orders and unregulated flow events. Table 8 outlines the water orders required for several circumstances with and without stock and domestic replenishments on Willandra Creek, Merrowie Creek and the Muggabah–Merrimajeel Creek systems.

Unregulated flows and translucent environmental flow events are important piggybacking opportunities. As an indication of what would be required to deliver environmental water to Moon Moon Swamp, the following information is provided on the February–March 2010 unregulated flow event. This event reached the commence-to-fill for Moon Moon and some water filled the lower parts of the swamp (P Packard (OEH) 2011, pers. comm.) but the extent of flooding has not been determined:

- The combined flow at Willandra Weir and Regulator was some 26,100 megalitres between February 21 and March 12 (includes flows above 200 ML/d). The maximum discharge reached 2,869 ML/d at the weir with a maximum of some 100 ML/d down Willandra Creek.
- The flow at Hillston Weir reached 2,170 ML/d and therefore some water may have passed into Middle Creek.
- Over the 30 days associated with the event, some 25,000 megalitres passed Whealbah gauge with a maximum of 2,200–2,300 ML/d for five days.

Table 7 provides information on the flow regime and total volumes of water that could be used to piggyback an environmental water order for assets/WMAs as relevant.

5.1.7 Asset/WMA antecedent moisture conditions

The moisture condition of the environmental asset/WMA is an important consideration in determining the water order. If the soil moisture profile of an asset/WMA is already wet, far less water will be required for the order than if the soil profile is dry. This situation is best illustrated by the water order which is required to reach sites in Murrumbidgil Swamp where much more water is needed in the absence of piggybacking environmental water on the stock and domestic replenishment, as outlined in Table 5. Equally, the volume of water required to inundate Murrumbidgil Swamp will be greater if the site is dry, than if the soil profile is already wet (Table 7).

Table 7: Wet and dry water orders for Murrumbidgil Swamp[1] (source – Water Management Area Profile)

	Wet order	Dry order
Merrimajeel Creek supply channel	Nil if already channel wetted and in winter months.	4,000 ML in winter (based on stock and domestic replenishment share of 7, 000 ML for Merrimajeel Creek).
Murrumbidgil Swamp (100 -ha area)	600 ML if swamp is wet.	1,400 ML if swamp is dry.
Total order	**600 ML**	**5,400 ML**

[1] Note that the following 'rule of thumb' method has been used to calculate estimates: 6 ML/ha (wet) and 12 ML/ha (dry) for wetland areas in the profiles. Additional to soil moisture, many other factors will have a significant influence on the actual watering requirement of the wetland such as soil type, depth and overall bathymetry of the sites, time of the year, etc. More accurate watering requirements can be obtained from the development and ongoing calibration of hydrodynamic and hydrology models for individual wetlands. The Barma et al. (2010) study has developed hydrology models for many of the subject Lachlan wetlands and provides the first calibration of these models.

Determination of wet-versus-dry condition soil-moisture profile of an asset/WMA is influenced primarily by flows from the Lachlan River and local rainfall. Objective measures of the soil-moisture profile, in relation to ecological water requirements for the site, can be obtained using instruments such as neutron probes.

In the absence of objective measures, 'time since last watering' can be estimated based on the relationship between river flow events and response thresholds (i.e. commence-to-fill) of the asset/WMA. The closest meteorological station can also provide information on the severity of rainfall events. This information can be provided by local landholders, and probably more accurately for the actual site conditions.

At the time of writing, no objective relationship has been established between watering events (either river flows or rainfall) and the soil-moisture profile conditions for the Lachlan assets (these may have differing soil types and consequently differing relationships). Therefore the assumption used in this document is that an asset/WMA is considered to be dry if it has not been wetted within a two-year period, and consequently will require a dry water order.

5.1.8 Efficient release below Lake Brewster

The maximum release for irrigation peak demand to the Hillston area, and for avoiding losses to Willandra and Middle Creeks, occurred in 2000. The amount released was 2,000 ML/d from Lake Brewster and Brewster Weir pool (some releases from Wyangala Dam were also involved to fill the weir pool). Flows in this vicinity to downstream wetlands are likely to be the most efficient in terms of the risk of losing water to the Willandra and Middle Creek systems.

Lake Brewster is especially important for the provision of environmental water, due to its storage and release capacity and its location in the catchment. In this context some important issues need to be considered about this storage:

- Lake Brewster is often dry or non-operational toward the end of each water year or during extended drought periods. For example, until the 2010–11 water year, Lake Brewster had not held water for stock and domestic releases or water allocations since 2001. The lake can also be empty or with low water levels in periods with high water allocations. Even with 100 per cent allocations it is common for the lake to be low or empty in year two of these circumstances due to the high downstream water demands in year one. Therefore there may be circumstances when the lake is dry or has limited water when environmental releases are wanted (also see bulk water transfers below).

- The lake frequently develops serious, toxic blue-green algal blooms (and other poor water-quality characteristics) and therefore releases have seeded the river downstream and resulted in algal warnings being issued. Under these circumstances releases from the lake have either been terminated or reduced, with 'make-up' water having to be released from Wyangala Dam. The Water Sharing Plan has provisions for these circumstances and there are operating protocols which restrict releases from the lake.
- Under the recently implemented Lake Brewster Water Efficiency Project, actions have been taken at the lake to reduce potential for poor water quality through the construction of inflow and outflow wetlands. At this stage it is not known how effective these wetlands will be, and particularly at low lake levels when water quality is at its worst.
- Given the significant growth in available environmental water on the Lachlan, and the pivotal importance of the lake in providing this water to the lower river, there is likely to be a growing need to ensure this water resides in the lake as much as possible. Provision of this water will likely be of a substantially different demand pattern (i.e. winter–spring, large volume and high-loss water orders—see Table 7) versus that which has traditionally been the case (i.e. summer, lower volume and low-loss water orders). As such, this need may require bulk environmental water transfers to be made from Wyangala Dam, which has not occurred previously in the Lachlan. This action could have major consequences such as impacts on the upstream river ecosystem, water loss through evaporation in the lake, and third-party impacts on other water users. There has been no investigation of bulk water transfers in the Lachlan as previously there has been no need for these.

5.2 Water orders for Lachlan environmental assets

The determination of delivery requirements, watering frequencies and duration for the water-dependent assets of the Lachlan River will be subject to the conditions existing at the desired time for watering and many dynamic considerations (some of these were outlined above). The actual water delivery specifications will be determined by State Water, to reflect delivery constraints and the environmental water order placed by environmental water managers.

The information in Table 8 is provided based on the water order which would be placed by environmental water managers to meet the ecological and environmental watering objectives for each asset/WMA presented in Table 5, and has drawn on the information of Table 6 to determine the timing and duration of watering. The water order in Table 8 considers the essential parameters that environmental water managers would provide to State Water as per their Water Order Application Form (see Appendix 4). The extraction details for bulk orders required under the order form are:

- start date
- number of days pumping (or duration of flow in the environmental assets)
- volume per day in megalitres.

There is also another State Water form for the use of multiple licences for the water order.

In addition, the water order in Table 8 considers the antecedent condition of the asset based on considerations outlined in section 5.1.6 above. Descriptions of each of the WMA and assets for which delivery regimes have been determined are provided in Appendix 2.

Because of the complexity and length of Table 8, Table 9 provides a summary of Table 8 water orders.

Table 8: Water orders to meet environmental watering objectives for Lachlan assets and water management areas.

Asset	WMA	Climate scenario (from Table 5)	Asset environmental watering objective[1]	Antecedent condition or time since last watering[2]	Water order[3,4]
Lachlan River channel	Lachlan River reach–Wyangala–Jemalong	Extreme dry	Baseflow to prevent cease-to-flow.	Wet	No watering action required, subject to 120 ML/d of conveyance and town water supply releases at Forbes delivered from Wyangala or unregulated flows. (Note: See section 5.1.5 and this volume will vary seasonally.)
				Dry	As above. Because this part of the river channel remains continuously wet, there is no additional dry requirement.
		Dry	As above.	Wet	No watering action required, subject to 120 ML/d of conveyance and town water supply releases at Forbes delivered from Wyangala or unregulated flows. (Note: See section 5.1.5 and this volume will vary seasonally.)
				Dry	As above.
		Median	Drownout Cottons Weir (Forbes) for 1 week.	Wet-	Drownout threshold is 9,250 ML/d or a total volume of 64,750 ML delivered over seven days is required to achieve this order. Can be achieved through Wyangala Dam release (see section 5.1.2) or piggybacking.
				Dry	As above.
		Wet	Drownout Cottons Weir (Forbes) for 2 weeks.	Wet	Drownout threshold is 9,250 ML/d, or a total volume of 129,500 ML delivered over 14 days is required to achieve this order. Can be achieved through Wyangala Dam release (see section 5.1.2) or piggybacking.
				Dry	As above.
	Lachlan River reach–Jemalong–Lake Cargelligo	Extreme dry	Baseflow to prevent cease-to-flow.	Wet	No watering action required, subject to conveyance and town water supply releases of 150 ML/d at Jemalong and 30 ML/d at Lake Cargelligo Weir. (Note: See section 5.1.5 and this volume will vary seasonally. Also, regulated flows may be stopped at Condo in these climate years.)
				Dry	As above. In the recent drought, regulated flows were maintained to Lake Cargelligo and the river channel remains wet.
		Dry	As above.	Wet	No watering action required, subject to conveyance and town water supply releases of 150 ML/d at Jemalong and 30 ML/d at Lake Cargelligo Weir. (Note: See section 5.1.5 and this volume will vary seasonally.)
				Dry	As above.
		Median	Drownout Condobolin and West Condobolin Weirs for 1 week.	Wet	Condo Weir threshold is 4,100 ML/d and a total order of 28,700 ML over 7 days is required. West Condo Weir threshold is 3,800 ML/d, requiring a total order of 26,600 ML over 7 days provided concurrently with the Condo Weir order. Can be achieved through Wyangala Dam release (see section 5.1.2) or piggybacking.
				Dry	As above.
		Wet	Drownout Condobolin and West Condobolin Weirs for 2 weeks.	Wet	Condo Weir threshold is 4,100 ML/d and a total volume of 57,400 ML over 14 days is required. West Condo Weir threshold is 3,800 ML/d, requiring a total order of 53,200 ML over 14 days provided concurrently with the Condo Weir order. Can be achieved through Wyangala Dam release (see section 5.1.2) or piggybacking.
				Dry	As above.

Asset	WMA	Climate scenario (from Table 5)	Asset environmental watering objective[1]	Antecedent condition or time since last watering[2]	Water order[3,4]
Lachlan River channel	Lachlan River reach–Lake Cargelligo– Lake Brewster	Extreme dry	Baseflow to prevent cease-to-flow.	Wet	80 ML/d at Lake Cargelligo Weir. (Note: See section 5.1.5 and this volume will vary seasonally. Also regulated flows may be stopped at Condo in these climate years.)
				Dry	As above.
		Dry	As above.	Wet	As above.
				Dry	As above.
		Median	Maintain inundation of Brewster Weir pool.	Wet	The full storage volume of Brewster Weir pool is 5,500 ML; olive perchlet refuges do not require full storage, appropriate storage volume to protect olive perchlet habitat is not known.
				Dry	As above.
		Wet	As above.	Wet	The full storage volume of Brewster Weir pool is 5,500 ML; olive perchlet refuges do not require full storage, appropriate storage volume to protect olive perchlet habitat is not known.
				Dry	As above.
	Lachlan River reach–Lake Brewster–Great Cumbung Swamp	Extreme dry	Baseflow to prevent cease-to-flow.	Wet	50 ML/d required at Booligal to maintain visible flow. (Note: See section 5.1.5 and this volume will vary seasonally.)
				Dry	In the recent drought, particularly in this reach, regulated releases for stock and domestic flows were restricted and substantial parts of the channel which are normally wet became dry. It is not known how much additional water is required to re-wet the dry channel portion.
		Dry	As above.	Wet	50 ML/d at Booligal to maintain visible flow. (Note: See section 5.1.5 and this volume will vary seasonally.)
				Dry	As above.
		Median	Drownout Willandra and Hillston Weirs for 1 week.	Wet	Willandra Weir threshold is 8,500 ML/d or a total volume of 59,600 ML delivered over 7 days. Hillston Weir threshold is 4,750 ML/d or 33,250 ML over 7 days. The maximum possible Brewster Weir and Brewster Lake release is 3,000 ML/d or 21,000 ML per week. Order for both sites only to be achieved with piggybacking.
				Dry	As above.
		Wet	Drownout Willandra and Hillston Weirs for 2 weeks.	Wet	Willandra Weir threshold is 8,500 ML/d or a total volume of 119,000 ML delivered over 14 days. Hillston Weir threshold is 4,750 ML/d or 66,500 ML over 14 days. The maximum possible Brewster Weir and Brewster Lake release is 3,000 ML/d or 42,000 ML for two weeks. Order for both sites only to be achieved with piggybacking.
				Dry	As above.

Asset	WMA	Climate scenario (from Table 5)	Asset environmental watering objective[1]	Antecedent condition or time since last watering[2]	Water order[3,4]
Burrawang West Lagoon	Burrawang West Lagoon	Extreme dry	Deliver up to 50 ML (volume-to-fill) to Burrawang West Lagoon.	Wet	Requires flows to Bumbuggan Weir via Bumbuggan Creek, or unregulated. Flows via Goobang and Yarrabandai Creek (total volume required to deliver 50 ML volume-to-fill is 420 ML; 30–50 ML/d over 8–14 days).
				Dry	As above.
		Dry	As above.	Wet	As above.
				Dry	As above.
		Median	As above.	Wet	As above.
				Dry	As above.
		Wet	Deliver >50 ML (volume-to-fill) to Burrawang West Lagoon.	Wet	Requires flows to Bumbuggan Weir via Bumbuggan Creek or unregulated. Flows via Goobang and Yarrabandai Creek (total volume required to deliver >50ML volume-to-fill is >420 ML; 30–50 ML/d over 8–14 days).
				Dry	As above.
Yarnel Lagoon	Yarnel Lagoon	Extreme dry	Deliver up to 360 ML (volume-to-fill) to Yarnel Lagoon.	Wet	Requires 9,360 ML to deliver 360 ML (volume-to-fill), subject to 9,000 ML replenishment flow delivered at 150 ML/d for 60 days at Wallaroi Creek gauge between October and April (threshold gauge height at Wallaroi Creek is 1.027 m).
				Dry	As above.
		Dry	As above.	Wet	As above.
				Dry	As above.
		Median	As above.	Wet	As above.
				Dry	As above.
		Wet	Deliver >360 ML (volume-to-fill) to Yarnel Lagoon.	Wet	Requires 9,360 ML to deliver 360 ML (volume-to-fill), subject to 9,000 ML replenishment flow delivered at 150 ML/d for 60 days at Wallaroi Creek gauge between October and April (threshold gauge height at Wallaroi Creek is 1.027 m).
				Dry	As above.

Asset	WMA	Climate scenario (from Table 5)	Asset environmental watering objective[1]	Antecedent condition or time since last watering[2]	Water order[3,4]
Booberoi Creek	Booberoi Creek	Extreme dry	Baseflow to maintain pools.	Wet	No watering action required, subject to 12,500 ML replenishment flow at 30–50 ML/d for 12 months from Booberoi Weir. The replenishment may not be available from regulated releases in extreme dry conditions. State Water advise 4,000 ML will reach the end of the Booberoi system.
				Dry	As above.
		Dry	As above	Wet	As above.
				Dry	As above.
		Median	Deliver flushing flows to Booberoi Creek up to 3,000 ML (additional to the replenishment flow).	Wet	Up to 3,000 ML in addition to 12,500 ML replenishment, to pulse 200 ML/d for 20 days between June to Sept from Booberoi Weir. The volume of water delivered is for dry antecedent conditions and less will be required under wet antecedent conditions. Currently it is not possible to deliver these higher flows into the creek due to major siltation in the creek near the regulator.
				Dry	As above.
		Wet	Deliver flushing flows to Booberoi Creek up to 3,000 ML (additional to the replenishment flow).	Wet	As above.
				Dry	As above.
Lake Brewster	Lake Brewster inflow wetland	Extreme dry	No water delivered under extremely dry conditions.	NA	The wetland is part of the Lake Brewster operational storage. 1,500 ML (volume-to-fill) is the filling requirement estimated by State Water. For the wetland to optimise its water-quality improvement function, inflows of less than 500 ML/d have been estimated. The Lake Brewster Water Use Plan outlines objectives for the water savings including assisting in the establishment and maintenance of constructed inlet and outlet wetlands. These water savings belong to the Australian Government but are administered by the NSW Office of Environment and Heritage. While the inflow wetland volume-to-fill has been estimated at 1,500 ML, required volumes based on the area of wetland (300 ha) are: • 1,800 ML for wet antecedent conditions order based on 6 ML/ha • 3,600 ML for dry antecedent condition order based on 12 ML/ha.
		Dry	Deliver at least 1,500 ML (volume-to-fill) to Brewster inflow wetland	NA	
		Median	As above.	NA	
		Wet	As above.	NA	
	Lake Brewster outflow wetland	Extreme dry	No water delivered under extremely dry conditions.	NA	

Asset	WMA	Climate scenario (from Table 5)	Asset environmental watering objective[1]	Antecedent condition or time since last watering[2]	Water order[3,4]
Lake Brewster		Dry	Deliver up to 5,000 ML to Brewster outflow wetland.	Wet	The wetland is part of the Lake Brewster operational storage and would be filled from the main lake or via channel sources. The total area of the 3 cells is 745 ha. While the outflow wetland volume-to-fill has been estimated at 5,000 ML, required volumes based on the area of wetland (745 ha) are: 4,470 ML for wet antecedent condition order based on 6 ML/ha 8,940 ML for dry antecedent condition order based on 12 ML/ha.
				Dry	No water delivered under dry antecedent conditions.
		Median	As above.	NA	The wetland is part of the Lake Brewster operational storage and would be filled from the main lake or via channel sources. The total area of the 3 cells is 745 ha. While the outflow wetland volume-to-fill has been estimated at 5,000 ML, required volumes based on the area of wetland (745 ha) are: 4,470 ML for wet antecedent condition order based on 6 ML/ha 8,940 ML for dry antecedent condition order based on 12 ML/ha.
		Wet	Deliver >5,000 ML to Brewster outflow wetland.	NA	
Willandra Creek	Willandra Creek–upstream reach (Willandra Regulator to Willandra Homestead Weir)	Extreme dry	Baseflows to wet channel and fill pools.	Wet	No watering action required, subject to 12,000 ML replenishment flow provided at 150 ML/d to Homestead Weir. The volume of water delivered is for dry antecedent conditions and less will be required under wet antecedent conditions.
				Dry	As above.
		Dry	As above.	Wet	As above.
				Dry	As above.
		Median	Deliver water (volume to be determined).	Wet	Deliver water (volume to be determined), piggybacked on replenishment flow.
				Dry	As above.
		Wet	As above.	Wet	As above.
				Dry	As above.

Asset	WMA	Climate scenario (from Table 5)	Asset environmental watering objective[1]	Antecedent condition or time since last watering[2]	Water order[3,4]
Willandra Creek	Willandra Creek–downstream reach (Homestead Weir to Balranald/ Ivanhoe Rd)	Extreme dry	Baseflows to wet channel and fill pools.	Wet	No watering action required, subject to 12,000 ML replenishment flow provided at 150 ML/d to Homestead Weir. The volume of water delivered is for dry antecedent conditions and less will be required under wet antecedent conditions.
				Dry	As above.
		Dry	As above.	Wet	As above.
				Dry	As above.
		Median	Deliver water (volume to be determined).	Wet	Deliver water (volume to be determined) piggybacked on the replenishment flow.
				Dry	As above.
		Wet	As above.	Wet	As above.
				Dry	As above.
	Morrisons Lake	Extreme dry	No water delivered under extremely dry conditions.	NA	None
		Dry	No water delivered under dry conditions.	NA	None
		Median	Up to 4,000 ML (volume-to-fill) delivered to Morrisons Lake (estimate provided by State Water).	Wet	Wet antecedent condition order based on 6 ML/ha = 1,560 ML which requires 10 days at 150 ML/d at Willandra Homestead Weir.
				Dry	Dry antecedent condition order based on 12 ML/ha = 3,744 ML or 25 days at 150 ML/d at Homestead Weir. (Note: State Water advise that the lake can be filled from the stock and domestic replenishment but only after the replenishment has reach Ivanhoe Road. This may satisfy the environmental watering objective, but if not, an environmental water order will be required.)
		Wet	As above.	NA	As above.

Asset	WMA	Climate scenario (from Table 5)	Asset environmental watering objective[1]	Antecedent condition or time since last watering[2]	Water order[3,4]
Merrowie Creek	Upper Merrowie Creek (offtake to Toms Lake)	Extreme dry	Baseflows to wet channel and fill pools.	Wet	No watering action required, subject to replenishment flow of up to 9,000 ML provided at 150 ML/d for about 6–8 weeks between June to Sept from Gonowlia Weir. Wet conditions likely to require <9,000 megalitres.
				Dry	No watering action required, subject to replenishment flow of up to 9,000 ML provided at 150 ML/d for about 6–8 weeks between June to Sept from Gonowlia Weir.
		Dry	As above.	Wet	No watering action required, subject to replenishment flow of up to 9,000 ML provided at 150 ML/d for about 6–8 weeks between June to Sept from Gonowlia Weir. Wet conditions likely to require <9,000 megalitres.
				Dry	No watering action required, subject to replenishment flow of up to 9,000 ML provided at 150 ML/d for about 6–8 weeks between June to Sept from Gonowlia Weir.
			As above.	Wet	No watering action required, subject to replenishment flow of up to 9,000 ML provided at 150 ML/d for about 6–8 weeks between June to Sept from Gonowlia Weir. Wet conditions likely to require <9,000 megalitres.
				Dry	No watering action required, subject to replenishment flow of up to 9,000 ML provided at 150 ML/d for about 6–8 weeks between June to Sept from Gonowlia Weir.
		Median	As above.	Wet	No watering action required, subject to replenishment flow of up to 9,000 ML provided at 150 ML/d for about 6–8 weeks between June to Sept from Gonowlia Weir. Wet conditions likely to require <9,000 megalitres.
				Dry	No watering action required, subject to replenishment flow of up to 9,000 ML provided at 150 ML/d for about 6–8 weeks between June to Sept from Gonowlia Weir.
		Wet	As above.	Wet	No watering action required, subject to replenishment flow of up to 9,000 ML provided at 150 ML/d for about 6–8 weeks between June to Sept from Gonowlia Weir. Wet conditions likely to require <9,000 megalitres.
				Dry	No watering action required, subject to replenishment flow of up to 9,000 ML provided at 150 ML/d for about 6–8 weeks between June to Sept from Gonowlia Weir.

Asset	WMA	Climate scenario (from Table 5)	Asset environmental watering objective[1]	Antecedent condition or time since last watering[2]	Water order[3,4]
Merrowie Creek	Merrowie Creek–Toms Lake	Extreme dry	Baseflows to wet channel and fill pools.	Wet	No watering action required, subject to replenishment flow of up to 9,000 ML provided at 150 ML/d for about 6–8 weeks between June to Sept from Gonowlia Weir. Wet conditions likely to require <9,000 megalitres.
				Dry	No watering action required, subject to replenishment flow of up to 9,000 ML provided at 150 ML/d for about 6–8 weeks between June to Sept from Gonowlia Weir.
		Dry	Deliver 3,000 to 3,600 ML.	Wet	3,000–3,600 ML provided at 150 ML/d for about 20 days, piggybacked on replenishment flow between Jun and Sept.
			As above.	Dry	As above.
		Median	Deliver 3,000 to 5,000 ML.	Wet	3,000–5,000 ML provided at 150 ML/d for about 30 days, piggybacked on replenishment flow between Jun and Dec. Wet conditions likely to require <9,000 megalitres.
				Dry	3,000–5,000 ML provided at 150 ML/d for about 30 days, piggybacked on replenishment flow between Jun and Dec.
		Wet	Deliver 5,000 to 7,200 ML.	Wet	5,000–7,200 ML provided at 150–300 ML/d for about 45 days, piggybacked on replenishment flow between Jun and Dec. Wet conditions likely to require <9,000 megalitres.
				Dry	5,000–7,200 ML provided at 150–300 ML/d for about 45 days, piggybacked on replenishment flow between Jun and Dec.
	Merrowie Creek–Mutherumbung Weir pool	Extreme dry	Baseflows to wet channel and fill pools.	Wet	No watering action required, subject to replenishment flow of up to 9,000 ML at 150 ML/d for about 6–8 weeks between June to Sept from Gonowlia Weir. Wet conditions likely to require <9,000 ML.
				Dry	No watering action required, subject to replenishment flow of 9,000 ML provided at 150 ML/d for about 6–8 weeks from Gonowlia Weir.
		Dry	Deliver 3,500 to 5,000 ML to Mutherumbung Weir.	Wet	3,500–5,000 ML provided at 150 ML/d for about 30 days, piggybacked on replenishment flow between Jun and Sep.
				Dry	No watering action required, subject to replenishment flow of up to 9,000 ML at 150 ML/d for about 6–8 weeks between June to Sept from Gonowlia Weir.
		Median	As above.	Wet	3,500–5,000 ML provided at 150–300 ML/d for about 30 days, piggybacked on replenishment flow between Jun and Dec.
				Dry	As above.
		Wet	Deliver 5,000–7,200 ML to Mutherumbung Weir.	Wet	5,000–7,200 ML provided at 150–300 ML/d for up to 45 days, piggybacked on replenishment flow between Jun and Dec.
				Dry	As above.

Asset	WMA	Climate scenario (from Table 5)	Asset environmental watering objective[1]	Antecedent condition or time since last watering[2]	Water order[3,4]
Merrowie Creek	Merrowie Creek–Cuba Dam	Extreme dry	Baseflows to wet channel and fill pools.	Wet	No watering action required, subject to 9,000 ML replenishment flow provided at 150 ML/d for about 6–8 weeks between June to Sept from Gonowlia Weir. Wet conditions likely to require <9,000 ML.
				Dry	No watering action required, subject to 9,000 ML of replenishment flow provided at 150 ML/d for about 6–8 weeks between June to Sept from Gonowlia Weir.
		Dry	Deliver up to 5,000 ML to Cuba Dam.	Wet	5,000 ML provided at 150–300 ML/d for about 30 days, piggybacked on replenishment flow between Jun and Sep.
				Dry	No watering action required, subject to replenishment flow of up to 9,000 ML provided at 150 ML/d for about 6–8 weeks from Gonowlia Weir between Jun and Sep.
		Median	As above.	Wet	5,000 ML provided at 150–300 ML/d for up to 30 days, piggybacked on the replenishment flow between Jun and Dec.
				Dry	As above.
		Wet	Deliver up to 7,200 ML to Cuba Dam.	Wet	5,000–7,200 ML provided at 150–300 ML/d for up to 45 days, piggybacked on the replenishment flow between Jun and Dec.
				Dry	As above.
	Merrowie Creek–Lake Tarwong and Tarwong Swamps	Extreme dry	No water delivered under extremely dry conditions.	NA	
		Dry	No water delivered under dry conditions.	NA	
		Median	Deliver up to 2,000 ML to Tarwong Lake.	Wet	Up to 2,000 ML provided at 150–300 ML/d for up to 13 days, piggybacked on replenishment flow between Jun and Dec.
				Dry	As above.
		Wet	Deliver up to 9,000 ML to Lake Tarwong and the south and north swamps.	Wet	Up to 9,000 ML provided at 150–300 ML/d for up to 60 days, in addition to the replenishment flow between Jun and Dec.
				Dry	As above.

Asset	WMA	Climate scenario (from Table 5)	Asset environmental watering objective[1]	Antecedent condition or time since last watering[2]	Water order[3,4]
Moon Moon Swamp	Moon Moon Swamp	Extreme dry	No water delivered under extremely dry conditions.	NA	
		Dry	No water delivered under dry conditions.	NA	
		Median	Deliver up to 2,500 ML (volume-to-fill) to Moon Moon Swamp.	Wet	The inflow channel capacities (i.e. filling rate) from the Lachlan River into the swamp are not known but 100 ML/d has been assumed. The following is known: • The CTF for these channels is about 2,000 ML/d at Whealbah. This flow rate for 30 days is known to result in the inundation of the swamp. In 2010 a total flow about 25,000 ML achieved flooding of Moon Moon. Timing is from June to December. • Wet: 1,050 ML at 100 ML/d for 10.5 days. • Dry: 2,500 ML at 100 ML/d for 25 days.
				Dry	
		Wet	Deliver up to 2,500 ML to Moon Moon Swamp (as above) and downstream environment.	Wet	
				Dry	
Booligal Wetland	Booligal Swamp	Extreme dry	Baseflows to wet channel and fill pools.	Wet	No watering action required, subject to replenishment flows of up to 9,000 ML provided at 100 ML/d for 90 days in winter. Less water required under wet antecedent conditions.
				Dry	No watering action required, subject to replenishment flows of up to 9,000 ML provided at 100 ML/d for 90 days in winter.
		Dry	As above.	Wet	No watering action required, subject to replenishment flows of up to 9,000 ML provided at 100 ML/d for 90 days in winter. Less water required under wet antecedent conditions.
				Dry	No watering action required, subject to replenishment flows of up to 9,000 ML provided at 100 ML/d for 90 days in winter.
		Median	Deliver up to 5,000 ML to Booligal Swamp.	Wet	Deliver up to 5,000 ML via diversion from Torriganny Weir into Merrimajeel Creek. Flows provided at 50 ML/d for up to 100 days. in addition to the replenishment flow between May and August.
				Dry	No watering action required as waterbird breeding unlikely in absence of prior wetting.
		Wet	As above.	Wet	Deliver up to 5,000 ML via diversion from Torriganny Weir into Merrimajeel Creek. Flows provided at 50 ML/d for up to 100 days. in addition to the replenishment flow between May and August.
				Dry	No watering action required as waterbird breeding unlikely in absence of prior wetting.

Asset	WMA	Climate scenario (from Table 5)	Asset environmental watering objective[1]	Antecedent condition or time since last watering[2]	Water order[3,4]
Booligal Wetland	Murrumbidgil Swamp	Extreme dry	No water delivered under extremely dry conditions.	NA	
		Dry	Deliver 1,400 ML (volume-to-fill) to Murrumbidgil Swamp.	Wet	Deliver 1,400 ML at 40 ML/d for 35 days from Torriganny Weir, piggybacked on replenishment flow.
				Dry	As above.
		Median	Deliver >1,400 ML (volume-to-fill) to Murrumbidgil Swamp.	Wet	Deliver 1,400 ML+ 4,000 ML= 5,400 ML (in the absence of replenishment flow) via Merrimajeel Creek at 100 ML/d for 54 days from Torriganny Weir from May to August.
				Dry	As above.
		Wet	As above.	Wet	As above.
				Dry	As above.
	Lake Merrimajeel	Extreme dry	No water delivered under extremely dry conditions.	NA	
		Dry	No water delivered under dry conditions.	NA	
		Median	Deliver 1,200 ML (volume-to-fill) to Lake Merrimajeel.	Wet	See Murrumbidgil Swamp order (1,400 ML + 4,000 ML in the absence of replenishment flow). An additional 600 ML to be added and for an additional 30 days from Torriganny Weir.
				Dry	See Murrumbidgil Swamp order. An additional 1,200 ML to be added and for an additional 30 days from Torriganny Weir.
		Wet	Deliver >1,200 ML to Lake Merrimajeel.	Wet	See Murrumbidgil Swamp order. An additional volume >1,200 ML to be added and for at least an additional 30 days from Torriganny Weir.
				Dry	See Murrumbidgil Swamp order. An additional volume >1,200 ML to be added and for at least an additional 30 days from Torriganny Weir.

Asset	WMA	Climate scenario (from Table 5)	Asset environmental watering objective[1]	Antecedent condition or time since last watering[2]	Water order[3,4]
Booligal Wetland	Lower Gum Swamp	Extreme dry	No water delivered under extremely dry conditions	NA	
		Dry	No water delivered under dry conditions	NA	
		Median	Deliver up to 3,400 ML (volume-to-fill) to Lower Gum Swamp	Wet	Deliver 400 ML at 40 ML/d for 10 days from Torrigany Weir, piggybacked on replenishment flow.
				Dry	Deliver 400 ML+ 3,000 ML= 3,400 ML (in absence of replenishment piggyback) via Merrimajeel Creek at 40 ML/d for 85 days from Torrigany Weir in May to August.
		Wet	Deliver up to 2,500 ML to Lower Gum Swamp	Wet	Deliver 2,500 ML at 40 ML/d for 62 days from Torrigany Weir, piggybacked on replenishment flow.
				Dry	No watering action required as waterbird breeding unlikely in absence of prior wetting.
Lachlan swamps	Lake Waljeers	Extreme dry	No water delivered under extremely dry conditions.	NA	
		Dry	Deliver up to 2,600 ML (volume-to-fill) to Lake Waljeers.	Wet	2,600 ML required. CTF is 800–1,200 ML/d at Booligal Weir. Lake inflows occur at about 100 ML/d therefore it takes 26 days to fill (or 20,800–31,200 ML at Booligal Weir). Delivered Jun–Dec.
				Dry	No water delivered under dry antecedent conditions.
		Median	Deliver up to 6,240 ML to Lake Waljeers.	Wet	6,240 ML required. CTF is 800–1,200 ML/d at Booligal Weir. Lake inflows occur at about 100 ML/d therefore it takes 62 days to fill (or 49,600–74,400 ML at Booligal Weir). Delivered Jun–Dec.
				Dry	As above.
		Wet	As above.	Wet	As above.
				Dry	As above.

Asset	WMA	Climate scenario (from Table 5)	Asset environmental watering objective[1]	Antecedent condition or time since last watering[2]	Water order[3,4]
Lachlan swamps	Peppermint Swamp	Extreme dry	No water delivered under extremely dry conditions.	NA	
		Dry	Deliver up to 1,440 ML (volume-to-fill) to Peppermint Swamp.	Wet	600 ML at 50–100 ML/d or 6–12 days. Delivered June–Dec.
				Dry	1,440 ML at 50–100 ML/d or 14–29 days. Delivered June–Dec. The orders are additional to those for Lake Waljeers and similarly the requirement for additional flows at Booligal Weir.
		Median	Deliver >1,440 ML (volume-to-fill) to Peppermint Swamp.	Wet	>1,440 ML at 50–100 ML/d or >20 days. Delivered June–Dec. The orders are additional to those for Lake Waljeers and similarly the requirement for additional flows at Booligal Weir.
				Dry	As above.
		Wet	Deliver >1,440 ML (volume-to-fill) to Peppermint Swamp.	As above.	As above.
Ita Lake	Ita Lake	Extreme dry	No water delivered under extremely dry conditions.	NA	
		Dry	Deliver up to 14,400 ML to Ita Lake.	Wet	Deliver 7,200 megalitres. The CTF for the lake is about 800 ML at Corrong based on recent changes to the regulator on the inflow channel. The relationship between Corrong flows and inflows volumes to the lake is not known. If it assumed 100 ML/d flows into the lake at a Corrong flow of 2,000 ML/d, it will take 72 days to provide the 7,200 ML (or about 140 GL at Corrong). To be delivered in June to Dec.
				Dry	14,400 megalitres. As above but for 144 days at 2,000 ML/d at Corrong required or 288,000 megalitres. To be delivered in June to Dec.
		Median	As above.	Wet	As above.
				Dry	As above.
		Wet	Deliver >14,400 ML to Ita Lake.	Wet	Deliver >14,400 megalitres. As above but for >144 days at 2,000 ML/d at Corrong required or >288,000 megalitres. To be delivered in June to Dec.
				Dry	As above.

Asset	WMA	Climate scenario (from Table 5)	Asset environmental watering objective[1]	Antecedent condition or time since last watering[2]	Water order[3,4]
Baconian Swamp	Baconian Swamp	Extreme dry	No water delivered under extremely dry conditions.	NA	
		Dry	Deliver up to 9,600 ML to Baconian Swamp.	Wet	Deliver 4,800 ML. The CTF for Baconian swamp is 350 ML/d at Corrong. The relationship between Corrong flows and inflow volumes to the swamp are not known. If 100 ML/d flows into the lake are assumed—at a Corrong flow of 1,500 ML/d, it would take 48 days to provide this requirement or a total Corrong flow of 72,000 ML. To be delivered in June to Dec.
				Dry	Delivery of 9,600 ML will follow the scenario above but will take 96 days of 1,500 ML/d at Corrong of 144,000 ML.
		Median	Deliver >9,600 ML to Baconian Swamp.	Wet	>9,600 ML. As above but will take >96 days of 1,500 ML/d at Corrong of >144,000 ML.
				Dry	As above.
		Wet	As above.	Wet	As above.
				Dry	As above.
Great Cumbung Swamp	Reed bed	Extreme dry	No water delivered under extremely dry conditions.	NA	
		Dry	Deliver up to 4,900 ML to reed bed.	Wet	Deliver 2,450 ML, provided at 700 ML/d at Booligal Weir for 3.5 days. Deliver in June to Dec.
				Dry	Deliver 4,900 ML, provided at 700 ML/d at Booligal Weir for 7 days. Deliver in June to Dec.
		Median	As above.	Wet	As above.
			As above.	Dry	As above.
		Wet	As above.	Wet	As above.
				Dry	As above.

Asset	WMA	Climate scenario (from Table 5)	Asset environmental watering objective[1]	Antecedent condition or time since last watering[2]	Water order[3,4]
Great Cumbung Swamp	GCS WMA	Extreme dry	No water delivered under extremely dry conditions.	NA	
		Dry	No water delivered under dry conditions.	NA	
		Median	Deliver up to 30,000 ML to GCS.	Wet	Deliver 15,000 ML, provided at 700 ML/d at Booligal for about 21 days. Deliver in June to Dec.
				Dry	Deliver 30,000 ML, provided at 700 ML/d at Booligal for about 43 days. Deliver in June to Dec.
		Wet	Deliver up to 45,000 ML to GCS.	Wet	Deliver 22,500 ML, provided at 700 ML/d at Booligal for about 32 days. Deliver in June to Dec.
				Dry	Deliver 45,000 ML, provided at 700 ML/d at Booligal for about 64 days. Deliver in June to Dec.

1 Table 5 provides the corresponding ecological objective.

2 For wetlands, 6 megalitres per hectare is used for wet and 12 megalitres per hectare used for dry conditions.

3 Water order does not include conveyance or piggybacking water requirements, although some indication of these requirements are given where known. The baseflows and water for consumptive use (e.g. replenishment flows) are not to be substituted by held environmental water. In instances when these flows are not provided, additional water may need to be provided from held environmental water to meet the watering objectives. In some systems this may not be feasible given the volume that would be required. Regardless of this, the water order parameters for the baseflows or water for consumptive use are provided.

4 Where possible, delivery constraints have been considered in the water orders provided above. However, delivery constraints (outlined in sections 5.1 and 10.1) must be reviewed prior to the implementation of watering actions.

Table 9: Summary of proposed environmental water-order volumes and delivery strategies

Asset	Volume Range for water order (site watering only)	Volume of replenishment flows	Additional water required, e.g. piggybacking	Other assets incidentally watered (Note: depends on water storage source)
Lachlan River channel	Current operational flows between 50–150 ML/d provides for some ecological objectives to be met at sites to Booligal. Weir drownouts: • Cottons: 64,750–129,500 ML • Condo: 28,700–57,400 ML • Willandra: 59,600–119,000 ML.	Operational flows and unregulated tributary flows undetermined.	Yes	None. Low-mid elevation wetlands and floodplain.
Burrawang West Lagoon	Up to 420 ML.	NA	NA	None
Yarnel Lagoon	Up to 360 ML (9,360 ML if not piggybacked).	9,000 ML	Yes	Wallaroi Creek riparian areas.
Booberoi Creek	Up to 3,000 ML (15,500 ML if not piggybacked).	12,500 ML	Yes	Return flows from Booberoi Creek to the Lachlan River downstream of Lake Cargelligo.
Lake Brewster	1,500 ML to >5,000 ML	Part of Lake Brewster water quality improvement.	NA	May be used to re-regulate environmental water.
Willandra Creek	4,000 ML up to volume to be determined (at least 16,000 ML if not piggybacked).	12,000 ML	Yes	Morrisons Lake
Merrowie Creek	3,000–9,000 ML (18,000 ML if not piggybacked).	9,000 ML	Yes	Lake Tarwong
Moon Moon Swamp	1,050–2,500 ML		Yes. 25,000 ML at Whealbah.	Willandra Creek and Merrowie Creek by 'additional water' to reach CTF.
Booligal Wetlands	400 ML to >6,600 ML (>15,600 ML if not piggybacked).	9,000 ML	Yes. Up to 20,000–50,000 ML from Torrigany required to stimulate for waterbird breeding.	Willandra, Merrowie, Moon Moon by 'additional water' to reach CTF.

Asset	Volume Range for water order (site watering only)	Volume of replenishment flows	Additional water required, e.g. piggybacking	Other assets incidentally watered (Note: depends on water storage source)
Lachlan Swamp	2,600–7,680 ML	NA	Yes. Up to 74,400 ML required at Booligal Weir to meet this order.	Willandra, Merrowie, Moon Moon and Booligal system by 'additional water' to reach CTF.
Lake Ita	7,200 ML to >14,400 ML	NA	Yes. Up to 288,000 ML at Corrong.	Willandra, Merrowie, Moon Moon, Booligal system and Lachlan Swamps by 'additional water' to reach CTF.
Baconian Swamp	4,800 ML to >9,600 ML	NA	Yes. Up to 144,000 ML at Corrong.	Willandra, Merrowie, Moon Moon, Booligal system, Lachlan Swamps and Lake Ita by 'additional water' to reach CTF.
Great Cumbung Swamp	2,450–45,000 ML	End of system flows.	Yes. 700 ML/d or greater at Booligal will result in additional GCS flooding.	700 ML/d (the delivery rate) will result in some flooding of Baconian. Higher flows will increasingly flood other areas.

6. Governance and planning arrangements

6.1 Delivery partners, roles and responsibilities

The partners involved in the provision of water to water-dependent assets in the Lachlan system include:

- NSW Office of Water—as the administrator of the Lachlan Water Sharing Plan and its environmental water provisions. There is an informal inter-agency agreement that has resulted in NSW Office of Water being responsible for rules-based environmental water (i.e. translucent and Water Quality Allowance) and NSW Office of Environment and Heritage being responsible for discretionary environmental water (Ecological Contingency Allowance).
- State Water as the water-delivery authority, which has extensive experience in operational aspects of the river, creeks and environmental water.
- NSW Office of Environment and Heritage as the managers of the water under the Lachlan Environmental Water Use Plan No. 1, and which have more recently become significant owners of wetland sites in the lower Lachlan. NSW Office of Environment and Heritage currently deliver Commonwealth environmental water under a temporary water-transfer arrangement.
- Lachlan CMA has sponsored the development of the draft Lachlan Environmental Water Management Plan and hosts the LRWG. The LRWG includes representatives from the LCMA, NSW Office of Water, NSW Office of Environment and Heritage, State Water, and conservation and community representatives, with staff from Commonwealth Environmental Water participating as observers. The LRWG advises the NSW Office of Environment and Heritage and the general manager of the Lachlan CMA on the management of the environmental water by assimilating a range of knowledge, experience and opinion in local community stakeholder groups and regional government agencies. Watering priorities are required to be consistent with the Lachlan Catchment Action Plan. The LRWG also provides advice on environmental needs in relation to regulated river operation on occasions when the Lachlan Water Sharing Plan is suspended.

6.2 Approvals, licences, legal requirements and other administrative issues

The RiverBank Lachlan Water Use Plan No. 1 sets out the legal requirements which are applicable to Water Use Plans. A Water Use Plan is a requirement for water access licences with Adaptive Environmental Water conditions under section 8E(7) of the *Water Management Act 2000* (NSW).

For environmental water managers who do not have a Water Use Plan allocated, environmental water can be transferred to the NSW Office of Environment and Heritage RiverBank for delivery. In this context, there are some relevant rules in the Water Use Plan No. 1 which are important:

- objectives of the plan
- accounting of water use which is undertaken at the following sites based on the areas targeted for water delivery:
  - Brewster Weir
  - Merrowie Offtake Regulator
  - Torriganny Weir
  - Merrimajeel Regulator
  - Muggabah Regulator
  - Booligal Weir—importantly, this site is used for accounting of all environmental water to the several downstream water-dependent assets
  - Yarnel Weir in Condobolin.

6.3 Lake Brewster arrangements

The Lake Brewster Water Efficiency Project, which was jointly funded by the Australian Government through the Water Smart Initiative, Lachlan CMA, State Water and Lachlan Valley Water, was implemented to:

- improve water quality and wetland environment within the lake
- increase hydraulic efficiency, thereby generating water savings
- enhance the role of Lake Brewster as an effective operational storage
- promote the wetland as a demonstration site for adaptive management of a large-scale constructed wetland.

The project's objectives were to improve hydrologic efficiency by reducing evaporation losses through the division of the lake into two cells and upgrading the regulator and channels. Water-quality improvements are to be achieved through increased aquatic plant growth and enhanced wetland function. Adaptive management will be achieved through the development and implementation of operational and monitoring plans.

As part of the Lake Brewster water efficiency works, a general security environmental water entitlement of 12,000 megalitres was created from the water savings and is vested with the Australian Government, subject to a draft Water Use Plan which is administered by the NSW Office of Environment and Heritage. The draft Water Use Plan makes up to 12,000 megalitres available for use in the Lake Brewster constructed wetlands to enhance opportunities for threatened and other native fish and waterbirds in Lake Brewster and the lower Lachlan, and to enhance river and wetland habitat in Lake Brewster and the lower Lachlan. This water used within the lake is accounted for at the Lake Brewster Inlet Regulator for environmental water use within the lake, or at Brewster Weir for use at the downstream sites specified under the RiverBank Water Use Plan above.

6.4 Relevant trading rules and constraints

The Water Sharing Plan prohibits:

- any dealing (trading) which would increase the total share components of access licences allowed to take water from the Lachlan River downstream of Booligal
- trading of access licences or share components between upstream of Lake Cargelligo and downstream of Lake Cargelligo until a full review is completed (see plan amendments); at the time of drafting this report it was not known if this review had proceeded
- any dealing that would result in the total share component in Willandra Creek exceeding 23,457 unit shares
- trading of access licences from the Lachlan Regulated River to effluent creeks which receive their water from the Lachlan.

These rules apply to permanent trades. Temporary trades are permitted but restricted between the areas upstream and areas downstream of Lake Cargelligo Weir, which may influence where water is purchased for environmental use. The reason for the trading prohibitions to Willandra, the effluent creeks and Lachlan downstream of Booligal is to protect the environment of these areas from potential irrigation expansion and consequent further changes to the flow regimes of these watercourses.

The Lake Cargelligo barrier was instituted to:

- prevent licences being transferred downstream of the lower lakes and therefore putting more demand on Wyangala water, which would reduce overall system water reliability
- allow for the assessment of the social, economic and environmental impacts of licences being transferred downstream of the lakes.

7. Risk assessment and mitigation strategies

This section outlines a number of system scale risks associated with the delivery of environmental water. Asset scale risks are outlined in the Lachlan asset profiles, included at Appendix 2.

The risk assessment outlined in Table 10 provides an indication of the risks associated with the delivery of environmental water in the Lachlan catchment. 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. A framework for assessing risks has been developed by SEWPaC and is included at Appendix 5. Note that the risk level in Table 10 is the unmitigated risk (i.e. prior to the implementation of any mitigation measures).

A number of risks may arise from environmental watering, particularly following prolonged dry periods. Some risks include poor water quality, ecological risks associated with inundation periods and timing, socio-economic risks associated with flooding, and hydrologic risks associated with inappropriate flow regimes. Mitigation measures to reduce these risks are addressed in Table 10 and will be important in informing appropriate environmental water delivery. Some examples of risks associated with water delivery are outlined below:

- Following a prolonged period of drought, the Lachlan River downstream of Condobolin ceased to flow in late 2009. The resumption of operational flows and tributary inflows to the lower Lachlan resulted in a blackwater event within the river channel, with low oxygen levels culminating in fish kills in residual pools downstream of Condobolin. Recession flows from the inundated floodplain around the Moon Moon Swamp area in 2010 also resulted in a minor black water event, however no fish kills were recorded. Some of the impacts resulting from blackwater events may have been mitigated by continuous in-channel flows, flushing flows or timing of water releases to reduce the influence of organic material.
- Environmental releases have resulted in major waterbird breeding events, where risks have been mitigated by constant monitoring, adaptive management and communication between landholders and water managers. These actions have resulted in the successful fledging of thousands of waterbirds.
- Carp breeding has also been noted following recent inundation of the Great Cumbung Swamp (GCS), Lake Brewster and Cargelligo, which are known carp breeding hotspots. The increase in carp numbers is likely to have adverse effects on native fish and possibly inhibit aquatic plant growth. The Lachlan River Revival Project has been established to address these issues and is a collaboration between the LCMA, Invasive Animals Cooperative

Research Centre, Investment and Infrastructure NSW—Fisheries, South Australian Research and Development Institute (SARDI), and a number of other agencies and Lachlan community groups. The project involves a number of strategies to reduce carp numbers, including targeting breeding locations with mechanical control structures known as carp separation cages. This work has shown that carp control during low-flow periods may be as important as during wet years, and that drying out of remnant habitats during summer may contribute greatly to reducing the population once high flows return. Commercial fishing of the mid and lower Lachlan has also occurred and produced the most significant removal of carp, with over 11 tonnes of carp taken from Lake Cargelligo between May and August 2009.

Table 10: Risk associated with water delivery in the Lachlan catchment.

Risk type	Description	Likelihood	Consequence	Risk level	Mitigation
Salinity	Lakes Brewster and Cargelligo—often sources for environmental water delivery—frequently have salinity levels higher than those normally found in the river due to evaporative processes. Released water from these sources may increase salinity levels in the river and delivery targets.	Likely	Moderate	Medium	The Water Sharing Plan has a 20,000 ML Water Quality Allocation available in Wyangala Dam for relief of water quality problems. See also blue-green algae below.
	Salinity may also increase in weir pools during low flow or no-flow periods.				Continuous flows during summer months.
Blue-green algal blooms	Toxic blue-green algal blooms have occurred frequently on the Lachlan, primarily on the lower river around and downstream of Lakes Cargelligo and Brewster, generally starting in summer months and extending into the late autumn. Releases from Lake Brewster have commonly been a seeding source for these blooms in the river downstream.	Likely	Major	High	The Water Sharing Plan has a 20,000 ML Water Quality Allocation available in Wyangala Dam for relief of water quality problems. Historically the water required from Wyangala to relieve algal blooms has been at relatively low discharges, 100–300 ML/d. If there are blue-green algal blooms in the Lake Brewster, the release of environmental water would be restricted.
Blackwater	Blackwater events can occur with periods of high flows following dry or low flow periods. This is due to the build-up of organic material in channels and on floodplains. Managed releases of environmental water could contribute to triggering a blackwater event following low flow periods.	Possible	Major	High	Timing of flows may reduce blackwater impacts, e.g. water delivered in cooler months. Dilution flows may also reduce blackwater impacts. Monitoring responses to inflows entering previously dry areas is required to inform management actions.
Acid sulphate soils	Acid sulphate soils have been found in a number of lower Lachlan Weir pools and Lake Cargelligo surrounds (Wallace 2010). Reduced water levels in these weir pools or Lake Cargelligo could result in releases from acid sulphate soils.	Possible	Major	High	Ensure weir pools are adequately inundated and/or flushed. Monitor weir pools and Lake Cargelligo for acid sulphate soils impacts.
Streambank/ channel erosion	Delivery of water may result in increased rates of erosion in streambanks and channels, particularly if rapid changes in water level occur.	Likely	Minor/moderate	Medium	Delivery of water in a manner to reduce impacts on streambanks and channels.

Risk type	Description	Likelihood	Consequence	Risk level	Mitigation
Inappropriate inundation of floodplain vegetation	Floodplain inundation of inappropriate duration resulting in the drowning or drying of vegetation.	Unlikely	Moderate	Low	Ensure floodplain surfaces are inundated for appropriate periods. Manage the release of environmental water so as not to extend the duration of flood events beyond the thresholds for key vegetation species.
Invasive species	Major carp-breeding hotspots have been identified in the Lachlan. These include Lake Cowal, Lake Cargelligo, Lake Brewster and Great Cumbung Swamp. Carp breeding is likely to increase when these areas are inundated. Lippia is an environmental threat found in most wetlands and riparian areas throughout the lower Lachlan. It can cause severe bank erosion, degradation of soil and water and displacement of native plant species. It is difficult to control once established.	Likely	Moderate	Medium	Lachlan River Revival Program underway investigating appropriate carp control mechanisms including carp separation cages (Gilligan et al. 2010). Inundation of wetlands for appropriate length of time to 'drown' lippia. Appropriate land management (e.g. grazing regime) to protect native vegetation.
Incomplete bird breeding	Drawdown of bird-breeding rookeries resulting in the abandonment of nests. Poor water quality resulting in bird illness or death (botulism).	Possible	Major	High	Monitoring of breeding sites—including water levels and water quality. Timely delivery of water to maintain water levels.
Fish stranding	Cease-to-flow within river and creek channels or rapid fall in wetland water levels can lead to a fish strandings, which may significantly reduce fish populations.	Possible	Major	High	Manage flows to prevent weir pool drying and ensure that recession is not too rapid.
Flooding	Flooding and isolation of properties, roads and irrigation pumps during environmental water delivery.	Possible	Moderate	Medium	Ensure water levels do not exceed flow recommendations (see section 5.1.3); communicate increases to landholders.

Note: Risk level is indicative of the unmitigated risk, prior to the implementation of mitigation measures.

8. Environmental water reserves

8.1 Environmental water provisions and holdings

The Lachlan Regulated River Water Sharing Plan (WSP) has the following provisions for providing environmental water (DIPNR 2004a).

All water above the plan extraction limit (a mean of 305,000 ML/yr) is reserved for the environment. This ensures that there is no erosion of the long-term average volume of water available to the environment during the life of the plan. On a long-term average basis, approximately 75 per cent of yearly flows in the river are protected for the maintenance of environmental health.

As noted in section 2, the WSP provides for the release of up to 350,000 megalitres of translucency flows between May and November, in addition to specified environmental water. Translucency flows are only released if more than 250,000 megalitres has entered Wyangala Dam since 1 January of that year.

Translucency flows can be released from Wyangala Dam from mid-May to mid-November. Inflows are passed through the dam and water extraction from some tributary inflows and Lakes Brewster or Cargelligo may be prohibited. Translucency flows may also be released from Lakes Cargelligo or Brewster, from the start of June to the end of November, if releases from Wyangala Dam are likely to cause flooding. Environmental water can be opportunistically released on top on an appropriately sized translucency event to improve efficiency and by increasing flow capacity lower in the system.

The Lake Brewster flow targets vary between 3,500 ML/d and 8,000 ML/d, depending on the inflows that are occurring at the time, the volume of water in Wyangala Dam, the volume of flows that have entered Wyangala Dam, and the volume of flows that have already passed Lake Brewster that year.

The total volume of translucent and tributary flows is up to 350,000 ML/yr measured at Brewster Weir (although Willandra Weir is more appropriate due to the complex flow arrangements at Lake Brewster and Brewster Weir).

The plan also provides for the following reserves of water (with no carryover):

- 10,000 megalitres of water in Wyangala Dam and 10,000 megalitres in Lake Brewster whenever the total volume of water available to general security access licences exceeds 50 per cent of the access licence share volume at the beginning of a water year, or reaches 75 per cent during a water year. Release of this water is to support waterbird or fish breeding, wetland watering or increase flow variability.
- 20,000 megalitres of water in Wyangala Dam each water year for the purpose of reducing salinity levels or mitigating blue-green algae outbreaks.

Supplementary extraction (or 'off-allocation' extraction) previously occurred when the dam spilled or high unregulated flows entered the regulated river. These flows, which were not allocated to specific users, were able to be extracted and did not count against the extractor's licenced allocations. Under the WSP, supplementary extraction is not permitted within the regulated Lachlan Valley. The regulated Lachlan does not include the regulated Belubula River where supplementary extraction is allowed. A WSP is currently being developed for the Belubula River and the status of supplementary extraction under this plan is currently unknown.

In the Lachlan, the following environmental water holdings exist as licensed water entitlements (Table 11).

Table 11: Environmental water entitlements on the Lachlan River

Holder	High security	General security
Commonwealth environmental water holdings[1]	733 unit shares	82,709 unit shares
NSW	1,000 unit shares	24,575 unit shares
Commonwealth environmental water holdings (Lake Brewster water savings)		12,000 unit shares
Others	None known	None known

[1]Note – Holdings as at October 2010.

8.2 Available water determinations and seasonal allocations

Available water determinations are announced following an ongoing resource assessment process, which firstly takes into account the essential requirements for running the river and for providing town water, stock and domestic supplies. Prior to the recent drought the resource assessment process on the Lachlan accounted for the water in storages (primarily Wyangala Dam) and the minimum inflow recorded over a 24-month period. With the recent drought it is understood that the minimum sequence for the resource assessment has been extended to cover a 36–48 month period of minimum inflows. It is not known what effect, if any, this change has on general security reliability.

The NSW Office of Water administers the following rules of the Water Sharing Plan for high and general security entitlements with assistance from State Water. These rules are listed below and are taken from the Lachlan WSP (DIPNR 2004a):

High security

The water supply system shall be managed so that available water determinations for regulated river (high security) access licences of 1 megalitre per unit share can be maintained during a repeat of the worst period of low inflows to this water source represented in flow information held by the department.

General security

An available water determination is not to be made for regulated river (general security) access licence holders in any water year until the sum of available water determinations for regulated river (high security) access licences for the water year is equivalent to 1 megalitre per unit share.

Immediately following the withdrawal of water allocations for high security, an available water determination for regulated river (general security) access licences shall be made. When Lachlan storages (Wyangala, Lake Brewster and Lake Cargelligo) spill, all general-security access licence accounts will be equalised. When Lachlan storages are full it should be possible for each general-security access licence account to hold a maximum 1.36 megalitres per unit share.

The available water determination for regulated river (general security) access licences shall be based on the volume available after making provision for:

(a) the environmental water provisions established by this plan

(b) requirements for domestic and stock rights

(c) requirements for native title rights

(d) requirements for domestic and stock access licences

(e) requirements for local water utility access licences

(f) requirements for regulated river (high security) access licences

(g) requirements for regulated river (conveyance) access licences

(h) allocations remaining in access licence water allocation accounts from previous available water determinations

(i) water loss associated with the holding and delivery of water to meet the requirements identified in subclauses (a) to (g)

(j) an appropriate volume to meet water losses associated with the holding and delivery of water resulting from the available water determination

(k) any other relevant matters.

8.3 Storage accounting rules

Water accounts for each type of entitlement are managed as described below (DIPNR 2004b).

A water allocation account has been established for each access licence. Water is credited to the account when an available water determination is made, or when water allocation is moved into the account from another access licence. Water is debited from the account when water is extracted or moved to another access licence.

The accounts of high-security access licences continue to be managed on an annual basis. This means that any water remaining in an account at the end of a water year is forfeit, and the account receives a new water allocation in the next water year. There is no account limit for high-security access licences during the year.

The accounts of general-security access licences operate continuously (i.e. continuous accounting of water account). There is no forfeit of water from accounts at the end of a water year. However, the volume that may be held in a general-security account at any time is limited to 2 megalitres per unit share. The accounts are split into two sub-accounts: one contains water that may be taken in the current water year (take water); the second contains water that can only be held for extraction in a future water year (hold water). Annually, at the start of each year, a take limit is announced by NOW and this will determine how much water is kept in the take account. The take account can be increased by trading in take account water. Whenever the Lachlan water storages fill, all water in general security accounts is 'withdrawn' and a new available water determination is made. This results in all general-security accounts being refilled equally to approximately 1.36 megalitres per unit share.

The following is a plain English version of the above based on LVW (2011)[3] and includes information on trade arrangements:

Continuous accounting limits, spill and trade arrangements:

- 200 per cent of entitlement is the maximum water that can be held in an account at any time.
- When all storages are full the general security share of the total system storage is 811,000 megalitres or 136 per cent of entitlement (this is the basis of the 1.36 unit share above).
- When there is a storage spill, all general-security accounts will be reset to a maximum of 136 per cent.
- There is no limit to the volume that can be transferred in any year, except that the account limit must always remain under 200 per cent.

Take and hold accounts:

- Each general-security water account has two sub-accounts:
  - The take sub-account is for water that can be used in the current year (also called A account).
  - The hold sub-account is for water that can be used in future years (also called B account).
- Water can be assigned (temporarily traded) from both the take and hold sub-accounts but cannot change its status as a result of trade. That is, water can be assigned from one take account to another take account or from one hold account to another hold account.

3 This fact sheet also provides a worked example of how an account might progress over a water year similar to 2011–12.

Take limit:

- An annual 'take limit' or use limit is applied to all general-security accounts to ensure that total valley usage remains within the WSP limit.
- The take limit sets the percentage of general-security entitlement that is available for use in that year, regardless of how much water is in the account.
- The take limit can vary up or down from one year to the next, but cannot exceed 100 per cent.
- The take limit runs for a full year and is not reset when there is a storage spill.
- The take limit is reset at 1 July every year. Unused take limit does not carry forward from one year to the next.
- The take limit for 2010–11 is 75 per cent of entitlement, not 75 per cent of the allocated water.
- The take limit for 2011–12 will be 100 per cent of entitlement (NOW February 2011).

8.4 Water delivery costs

The water charges which apply to water entitlements and water use in the Lachlan are listed in Table 12.

Table 12: Water charges for Lachlan water entitlements and use.

Charges to 30 June 2011*	High security	General security
Entitlement charge ($/ML)	$8.83	$3.96
Usage charge ($/ML)	$15.29	$15.29
Resource management (Office of Water) charge ($/ML)	$2.12	$1.17

*Charges rise progressively until June 2014 when the next IPART determination is made

Costs incurred for infrastructure maintenance by State Water is covered by these charges.

At the time of writing there is no pumping of water to assets in the Lachlan and therefore no costs associated with this.

PART 3:
Monitoring, evaluation and improvement

9. Monitoring, evaluation and improvement

While the MDBA has developed a monitoring and evaluation framework, the details of compliance, monitoring and reporting methods are yet to be determined. A number of monitoring programs are being undertaken by a variety of agencies in the Lachlan with some having a Basin-wide focus. These programs range from ecological to hydrological in nature and are listed below.

9.1 Current monitoring and reporting

9.1.1 Water quality and ecological reporting

The NSW Office of Water carries out monitoring of basic water-quality indicators such as nutrient and algal sampling across the Lachlan catchment. Salinity is also measured continuously at 17 sites. State Water undertakes water quality monitoring in Lachlan storages, particularly algal sampling during the warmer months. Both river and storage water quality information can be found on the NSW Water Information website. Water-quality monitoring that was undertaken as part of the Integrated Monitoring of Environmental Flows (IMEF) program is described below.

Established in 1997, the IMEF program was managed by the NSW Office of Water, with support from Industry and Investment NSW and researchers. The program finished in 2011.

The program assessed the ecological benefits of the environmental flow rules. The objectives of the IMEF program were:

- to investigate relationships between water regimes, biodiversity and ecosystem processes in the major regulated river systems, and the Barwon-Darling River
- to assess responses in hydrology, habitats, biota and ecological processes associated with specific flow events targeted by environmental flow rules
- to use the resulting knowledge to estimate likely long-term effects of environmental flow rules and provide information to assist in future adjustment of rules.

IMEF provided scientific information to review and inform water sharing plans, as well as adding to the understanding of the biodiversity and ecological processes in NSW rivers and wetlands. Projects conducted as part of IMEF included:

- examining how environmental flows can improve the ecology of NSW's rivers by increasing the supply of dissolved organic carbon to nourish the aquatic food chain
- assessing the ecological benefits of protecting natural low flows, and protecting or restoring the natural peak flows from Burrinjuck Dam to the Murrumbidgee River
- investigating the benefit of environmental flows for wetland habitat and biodiversity in the Lachlan and Namoi Rivers and in the Macquarie Marshes and Gwydir/Gingham wetlands
- investigating how environmental flows affect stratification of temperature and dissolved oxygen within the weir pools of the lower Darling River—it is hoped the flows can be used to avoid conditions that encourage excessive growth of blue-green algae and kill fish by oxygen starvation
- investigating the use of environmental flows released from dams to maintain the abundance of fish hatchlings when their survival is threatened by drought and unnatural patterns of water flow in regulated rivers.

In 1998–2000, five lower-Lachlan weir pools were monitored to assess the effects of flows on flushing algal blooms from the weir pools (Mitrovic et al. 2005). Water-quality variables, including nutrients, turbidity, temperature and algal cell numbers were measured in each weir pool.

It was found that Lakes Brewster and Cargelligo were likely contributors to blue-green algae in downstream weir pools. When water from Wyangala Dam replaced the lake flows, algal numbers dropped significantly. The reduction of blue-green algae concentrations occurring concurrently with water delivery from Wyangala Dam resulted in the Lower Lachlan Storages Algal Protocol being developed by the NSW Office of Water to manage blue-green algal blooms in the lower weir pools, and the development of the Water Quality Allowance as part of the WSP.

Detailed ecological monitoring of wetlands and fish was undertaken as part of the IMEF program to assess the effects of environmental flow rules. A number of variables were measured at 12 wetland sites located downstream of Forbes to the Cumbung Swamp. Variables measured included wetted area, macroinvertebrates, plants, frogs and birds (Driver et al. 2010). An assessment of fish populations was also undertaken at 10 river sites along the length of the Lachlan. Fish population assessments (species, size and condition) and habitat descriptions, were undertaken at each site (Growns 2008).

9.1.2 Sustainable Rivers Audit

The MDBA's Sustainable Rivers Audit (SRA) is a systematic assessment of the health of river ecosystems in the Basin. It is overseen by a panel of independent ecologists—the Independent Sustainable Rivers Audit Group (ISRAG)—and carried out by a number of agencies including the NSW Office of Water and Industry and Investment NSW. Quantitative information on environmental indicators is collected in valleys throughout the Basin. The indicators provide an insight on particular components of the river ecosystems. At this stage there are 'themes' for hydrology, fish and macroinvertebrates.

Within each valley there are zones defined by altitude, with sampling sites randomly located within the zones to enable unbiased statistical analyses and representative reporting. Indicators are combined to form quantitative measures of environmental condition for each theme. Condition is rated on a five-point scale from good to extremely poor, depending on how different the theme components are from their respective reference benchmarks.

SRA studies have found that the flow regime has significantly changed from the reference condition in the Lachlan and Belubula Rivers downstream of Wyangala and Carcoar storages. These reaches showed significant changes in the magnitudes of high, low and annual flows, and in flow variability and seasonality.

The SRA fish assessment in the Lachlan resulted in the catchment receiving the equal fifth-lowest score in the Basin. The Slopes Zone community showed a significant difference from the reference condition, with extremely low nativeness and exceptionally low native biomass (0.4 per cent of total fish biomass). The macroinvertebrate assessment was in the mid-range of scores in all valleys, with most site communities showing a large difference from the reference condition, and the Slopes Zone in poorest condition. In general, the Lachlan Valley river ecosystem was found to be in very poor health (Davies et al. 2008).

9.1.3 Rivers Environmental Restoration Program monitoring and reporting

The NSW Office of Environment and Heritage undertakes a number of ecological response projects as part of the Rivers Environmental Restoration Program (RERP). These projects are intended to improve knowledge of target wetlands by understanding the trophic dynamics of food webs, surveying fish and waterbirds, determining the extent of vegetation communities and their response to flooding. Other projects include understanding how the endangered (*Threatened Species Conservation Act 1995* (NSW)) southern bell frog (*Litoria raniformis*) responds to environmental flows and predators in the Lowbidgee floodplain, and documenting the ecological character of the Lowbidgee floodplain and lower-Lachlan wetlands.

9.1.4 Hydrological monitoring and reporting

The NSW Office of Water has an extensive hydrographic network which records river water levels and flows, storage elevations, volumes and discharges, and continuously monitors electrical conductivity from locations across NSW. This provides critical information in determining flow heights and durations required to appropriately inundate wetland targets.

The Integrated Quantity and Quality Hydrological Model (IQQM) has been developed to support water management planning, including the allocation and management of environmental water. IQQM runs simulate 'undeveloped' long-term flow conditions as well as current river flow scenarios.

The Lachlan IMEF project links ecology and hydrology, and looks at the effects of releasing water to restore a portion of the natural variability of river flows, including peak flows and the effectiveness of environmental flows on replenishing Lachlan wetlands (Driver et al. 2005). This knowledge is used to estimate the long-term effects of environmental flows provided under the Lachlan Regulated Source Water Sharing Plan.

The results of this project have confirmed the importance of the pattern of flow and inundation of wetlands in the Lachlan Valley. They have shown that:

- Booligal swamp requires flooding to be maintained for about 90 days to start a breeding event that could establish between 20,000 and 100,000 ibis nests.
- In 2005 the WSP succeeded in delivering extra flows to some targeted wetlands, while reducing the supply of irrigation water by about 3 per cent.
- Environmental flows were not equally shared, with the greatest volume of extra water going to Willandra Creek.
- The Great Cumbung Swamp needed more flooding to sustain its river red gums.

Hydrological projects undertaken by the NSW Office of Environment and Heritage, as part of RERP, aim to improve knowledge about wetland flood regimes and patterns. This is achieved through the development of hydrodynamic models of water movement through wetlands, by the expansion of river hydrology models to include floodplain wetlands, and the development of maps showing the historic inundation of wetlands.

Other projects include a project funded by the NSW Office of Water to provide technical information to support the implementation of the Water Sharing Plan, and to manage licensed environmental water by determining flow relationships under different climatic conditions for a selection of nationally important wetlands. The project also examined the effectiveness of translucency, environmental contingency allowance (ECA) and other environmental water in meeting flow objectives (Barma et al. 2010).

A complementary study, funded by the Lachlan Catchment Management Authority (LCMA), aimed to provide support to the LCMA in managing selected wetlands for improved biodiversity conservation. The project explored the relationship between flow magnitude and duration at each wetland offtake, and the duration and extent of inundation within the wetlands. It assessed the change in natural frequency, timing and duration of critical inundation events, and identified all of the feasible river operational and structural options that could be applied to restore ecologically significant components of the natural inundation (BWR 2010).

LCMA is also funding a project which involves spatially explicit flood monitoring to target small areas within the Great Cumbung Swamp. This project will enable the prediction flow inundation relationships in relation to given inflows and climatic conditions, and also assess the influence of floodplain structures once inflow events spread onto the floodplain. This will be achieved by incorporating recently acquired LiDAR data and hydrologic modelling to assess flow distribution for existing and proposed conditions in the Great Cumbung Swamp.

The CSIRO, in collaboration with other groups, has been developing and linking hydrological models to provide support for integrated surface water planning across the Basin, including modelling of river flows and water availability. The CSIRO has linked models to assist the MDBA to evaluate alternative scenarios and has included environmental water demands in the models.

The CSIRO has also reviewed water availability in the Lachlan in the context of future climate and development impacts, and predicted that these impacts would reduce the average end-of-system flows by a total of 15 per cent. Development would impact high-security town water supplies, and reduce the ECA by 4 per cent in addition to the climate change impacts. However, projected future catchment and groundwater development would have no additional effect on the frequency of floods reaching the Booligal Wetlands, and result in only small additional increases in the average period between winter-to-spring flood events for the Great Cumbung Swamp (CSIRO 2008).

9.2 Proposed monitoring and reporting

Table 13 lists possible monitoring options to measure and report environmental watering outcomes.

Table 13: Lachlan River system: monitoring parameters for environmental watering.

WMA	Objective	Hypotheses	Flow component	Indicator(s)	Monitoring sites	Frequency	Linkages and other considerations
Whole of river channel	Provide fish refuge during low-flow periods.	Pools within Lachlan channel will support native fish species during low/no-flow periods.	Baseflow	Native fish survival	Fisheries sites	To coincide with low flows.	Complement monitoring undertaken as LCMA drought refuge study.
Whole of river channel	Provide fish passage through weir drownout.	Fish will traverse weirs when drowned out by high flows.	High flows	Native fish movement	Fisheries sites	To coincide with high flows.	Complement existing NSW I&I monitoring programs.
Whole of river channel	Appropriate flow regime will provide habitat and breeding opportunities for native fish.	Sufficient flows will provide habitat and breeding opportunities for native fish.	Under all flow conditions.	Native fish population diversity, condition and numbers. Successful breeding events.	Existing NSW I&I sites.	1–3 years.	Existing NSW I&I monitoring.
Lower-Lachlan floodplain	Provide connectivity for the transport of sediments, nutrients and energy. Provide for the movement of aquatic biota.	Hydrologic connectivity through the inundation of floodplain wetlands will achieve energy exchange and allow movement of aquatic biota.	Medium to high flows.	Water level and timing, magnitude and flow frequency. Inundation area (mapping).	Lower Lachlan wetland sites	Flow-dependent	IMEF and community monitoring.
Channels and inundated wetlands	Provide appropriate flows to maintain or improve water quality.	Appropriate flow management will assist in maintaining and/or improving water quality.	Under all flow conditions.	Physicochemical responses to environmental flows.	Existing riverine NoW water quality sites. Existing IMEF wetland sites.	Dependent on season and inundation.	NoW, State Water water quality sampling; IMEF
Floodplain wetlands	Provide appropriate flooding to maintain and/or enhance semi-permanent and permanent wetland vegetation.	Appropriate flooding regimes will assist in maintaining or improving wetland vegetation (e.g. common reed, river red gum, lignum, black box) provide important feeding, breeding and refuge habitats.	Under all flow conditions.	The condition and extent of wetland vegetation communities.	Existing IMEF sites and key water-delivery targets.	Pre and post inundation.	IMEF and community monitoring.

WMA	Objective	Hypotheses	Flow component	Indicator(s)	Monitoring sites	Frequency	Linkages and other considerations
Bird breeding sites	Provide sufficient flows to provide waterbird habitat and complete breeding.	Sufficient flows will provide habitat and breeding opportunities for waterbirds.	Moderate to high flows	Waterbird population diversity, condition and numbers. Successful waterbird breeding events.	Waterbird breeding sites e.g. Merrowie and Booligal systems.	Inundation events	IMEF; existing community waterbird surveys
Floodplain wetlands	Appropriate flow regime will provide habitat and breeding opportunities for frogs.	Sufficient flows will provide habitat and breeding opportunities for frogs.	Moderate to high flows	Frog population diversity, condition and numbers. Successful frog breeding events.	Floodplain wetland sites	Inundation events	Existing OEH and IMEF monitoring.
Floodplain wetlands	Determine wetland antecedent condition.	Accurate determination of antecedent condition will better inform watering decisions.	All flows	Soil moisture or time since last inundation.	Floodplain wetland sites.	Prior to watering decisions.	Methods to be determined; may be linked to community monitoring.

10. Operational constraints and opportunities

10.1 Constraints

The operational constraints for delivering water in the lower parts of the Lachlan catchment are largely covered in previous sections, however, the following points are re-emphasised:

- There is considerable travel time from Wyangala Dam to many of the lower-river assets. It takes up to 60 days for water to travel from Wyangala Dam to the Great Cumbung Swamp (GCS). There are also major channel capacity constraints for the efficient delivery of large discharge releases from the dam, starting with the reduced channel capacity of the Condobolin Anabranches including a channel capacity of approximately 4,000 ML/d in Island Creek, 2,000 ML/d in the Goobang/Bumbuggan system, 390 ML/d in the Wallamundry and 175 ML/d in Booberoi Creek (S. Sritharan, State Water, pers. comm.).
- The generally long water delivery travel times for most of the assets on the lower river, even with delivery from the lower lakes, is an important consideration for environmental water management.
- Releases from the lower lakes will be the most efficient for delivery of environmental water to the lower river assets. However, there is significant potential for water loss to Willandra Creek, which has a lower commence-to-fill due to the current regulator than under natural conditions. Releases above 2,400 ML/d at Willandra Weir are also around the commence-to-fill for several of the downstream assets.
- Delivery of environmental water to the GCS is greatly complicated by the operation of water control structures, some of which are unauthorised, within the swamp. It should also be noted that many of these structures have existed in the GCS for many years and have resulted in changes in associated vegetation due to altered hydrology.

10.2 Opportunities

As indicated by the information presented in previous sections, the use of environmental water is often conducted in conjunction with 'other' water. The 'other' water includes translucency events, unregulated events (which may or may not be accounted as translucency), stock and domestic replenishment flows and other water orders. The stock and domestic replenishments offer particular opportunities for watering of assets along Willandra Creek, Merrowie Creek and the Muggabah/ Merrimajeel creeks systems. Translucency and unregulated flow events offer the opportunity for integrated watering of multiple sites depending on their hydrological characteristics. These events can be enhanced with releases of environmental water, particularly if there is sufficient water in the lower lakes.

Water management infrastructure is available to divert water to several sites (i.e. Willandra Creek, Merrowie Creek and the Booligal System) but not to others (i.e. Moon Moon Swamp, Lachlan Swamps, Ita Lake and Baconian Swamp). However, there are other potential opportunities for environmental watering based on the previous work of BWR (2010), which are summarised in Table 14. A similar analysis for other sites (e.g. Lachlan Swamps) could be undertaken.

The BWR (2010) study was undertaken for the LCMA with the specific purpose of identifying delivery constraints and options for improving water delivery to a number of lower Lachlan wetlands. The study assessed water requirements and water-delivery options using limited available data for the sites noted in Table 14. It relied on the limited satellite imagery used for the Barma et al. (2010) hydrological modelling study and interpolations of limited flow events to identify the areas of wetlands flooded, volume-to-fill and commence-to-fill thresholds.

The study was unable to establish a commence-to-fill for Lower Gum Swamp, but did identify reasonably accurate commence-to-fill levels for the other wetlands with the exception of Ita Lake (refer to Appendix 2). For some off-river sites (e.g. Moon Moon Swamp), while it was possible to identify reasonably accurate volume and commence-to-fill thresholds, it was not possible within the study to identify with any degree of accuracy the duration of the commence-to-fill needed to be maintained to achieve the required volume-to-fill, and therefore more accurately identify the flow volumes required in the river to achieve substantial, or the 'required', inundation.

Table 14: Summary of environmental watering opportunities for selected Lachlan assets (amended from BWR 2010).

Wetland	AEW release	Piggybacking	Existing irrigation
Moon Moon Swamp	A release of 25,000 ML and discharge of 2,800 ML/d at Willandra Weir is likely to flood a core area. Significant losses will occur at Willandra, Middle and Merrowie creeks.	Possible.	"Gunbar Station" has existing irrigation infrastructure including a channel which could be modified to deliver water directly to the swamp. This channel follows adjacent to the Booligal-Gunbar Road near Moon Moon Swamp, a distance of about 4 km.
Murrumbidgil (Angora) Lake Merrimajeel	Good efficiency with existing infrastructure if water from Brewster. A release of about 5,000 ML, but only in cold months. Warm month release not likely to reach swamp.	1,000 ML for Murrumbidgil Swamp on top of the stock and domestic replenishment. Similar volume required for Lake Merrimajeel.	There is a possible option to extend irrigation channels which supply nearby properties from Booligal Weir and pump sites. A channel of some 3.5 km would have to be constructed to the swamp from a channel adjacent to Boxyards Road.
Lower Gum	Good efficiency with existing infrastructure if water from Brewster. Lower Gum Swamp is not inundated by the stock and domestic flow. CTF is not known. More investigation required.	A possible option once CTF established.	There is an irrigation layout about 1.2 km south-east of the swamp and an irrigation channel some 1.6 km to the south, adjacent to Boxyards Road (this is the same channel which runs closest to Murrumbidgil Swamp). There is also a smaller channel which is used to fill a stock dam at the western edge of the swamp.
Ita Lake	A specific environmental water release is an unrealistic option due the high level CTF and water losses upstream[1].	Piggybacking of environmental releases on top of translucency releases or floods could be undertaken but with very high losses[1].	Existing irrigation infrastructure, if rehabilitated, offers opportunity for watering of parts of the lake but more investigations are required, particularly: • the capacity of the current pump and channel to flood (parts of) the lakebed • the extent of potential water losses along the supply channel.
Baconian Swamp	A release of around 35,000 ML at 2,800 ML/d at Willandra Weir is likely to flood at least some parts of the swamp.	A possible option.	Existing 30 cm pump, channel and irrigation layout to the south of the swamp offers opportunity. It may require upgrading to meet swamp inundation requirements. Also, two pumps and channels just downstream of the swamp.

[1] Subsequent to the BWR (2010) study the regulator on the inflow channel to Lake Ita was removed. During the 2011 flood event the commence-to-fill to the lake was determined to be at around 800 ML/d at Corrong. Inflows to the lake also occurred during this event via Pimpara Creek but the source of this water remains unknown.

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Appendix 1: Lachlan species list

Key: LC = Least concern; NT = Near threatened; V and VU = Vulnerable; E and EN = Endangered; M = Migratory; Y = Yes

Type	Common name	Scientific name	Status	Presence of species/ species habitat	Breeding status	Water dependency (Yes/No)	EPBC Act	CAMBA	JAMBA	ROKAMBA	IUCN Red list	state gov. listing
Bird	Australasian bittern	*Botaurus poiciloptilis*	Endangered (NSW)	Known	Unknown	Yes					EN	E
Bird	Great egret	*Ardea alba*		Known	Likely	Yes	M	Y	Y		LC	
Bird	Blue-billed duck	*Oxyura australis*	Vulnerable (NSW)	Known	Known	Yes					NT	V
Bird	Freckled duck	*Stictonetta naevosa*	Vulnerable (NSW)	Known	Likely	Yes					LC	V
Bird	White-bellied sea eagle	*Haliaeetus leucogaster*	Vulnerable (NSW)	Known	Likely	Yes	M	Y			LC	
Bird	Painted snipe	*Rostratula australis*	Vulnerable (EPBC)	Likely	Unknown	Yes	V, M	Y				E
Bird	Brolga	*Grus rubicunda*	Vulnerable (NSW)	Known	Likely	Yes		Y	Y		LC	V
Bird	Black-tailed godwit	*Limosa limosa*	Vulnerable (NSW)	Likely	unlikely	Yes	M	Y	Y		NT	V
Bird	Latham's snipe	*Gallinago hardwickii*		Likely	Unknown	Yes	M	Y	Y	Y	LC	
Bird	Pink-eared duck	*Malacorhyncus membranaceus*		Known	Likely	Yes					LC	
Bird	Magpie goose	*Anseranas semipalmata*	Vulnerable (NSW)	Likely	Unlikely	Yes					LC	V
Bird	Glossy ibis	*Plegadis falcinellus*		Known	Known	Yes		Y			LC	
Bird	Superb parrot	*Polytelis swainsonii*	Vulnerable (EPBC)	Known	Likely	No	V				VU	V
Fish	Purple-spotted gudgeon (relocated)	*Mogurnda adspersa*	Endangered (NSW)	Likely	Likely	Yes						E

Type	Common name	Scientific name	Status	Presence of species/ species habitat	Breeding status	Water dependency (Yes/No)	EPBC Act	CAMBA	JAMBA	ROKAMBA	IUCN Red list	state gov. listing
Fish	Olive perchlet	*Ambassis agassizii*	Regionally endangered (NSW)	Known	Known	Yes						RE
Fish	Murray cod	*Maccullochella peelii peelii*	Vulnerable (EPBC)	Known	Known	Yes	V				VU	
Fish	Macquarie perch	*Macquaria australasica*	Endangered (EPBC)	Known	Known	Yes	E				EN	E
Fish	Golden perch	*Macquaria ambigua*		Known	Known	Yes						
Fish	Silver perch	*Bidyanus bidyanus*	Vulnerable (NSW)	Known	Likely	Yes						V
Fish	Freshwater catfish	*Tandanus tandanus*	Endangered (NSW)	Known	Likely	Yes						E
Fish	Southern pygmy perch	*Nannoperca australis*	Endangered (NSW)	Known	Likely	Yes						
Fish	Unspecked hardyhead	*Craterocephalus fluviatilis*	Critically endangered (NSW)	Likely	Likely	Yes	V					
Fish	Northern river blackfish	*Gadopsis marmoratus*	Threatened (NSW)	Unknown	Unknown	Yes						T
Frog	Southern bell frog	*Litoria raniformis*	Vulnerable (EPBC)	Known	Unknown	Yes	V					E
Frog	Yellow-spotted bell frog	*Litoria castenea*	Endangered (EPBC)	Known	Likely	Yes	E					
Frog	Sloane's froglet	*Crinia sloanei*	Vulnerable (NSW)									V
Turtle	Broad-shelled snake-necked turtle	*Chelodina expansa*		Likely	Unknown	Yes						
Turtle	Eastern snake-necked turtle	*Chelodina longicollis*		Known	Known	Yes					LC	

Type	Common name	Scientific name	Status	Presence of species/ species habitat	Breeding status	Water dependency (Yes/No)	EPBC Act	CAMBA	JAMBA	ROKAMBA	IUCN Red list	state gov. listing
Turtle	Murray short-necked turtle	*Emydura macquarii*		Known	Known	Yes						
Vegetation	River red gum	*Eucalyptus camaldulensis*		Known	Known	Yes						
Vegetation	Black box	*Eucalyptus largiflorens*		Known	Known	Yes						
Vegetation	Lignum	*Muehlenbeckia florulenta*		Known	Known	Yes						
Vegetation	Weeping myall	*Acacia pendula*	Endangered (EPBC)	Known	Known	No	E					
Vegetation	Common reed	*Phragmites spp*		Known	Known	Yes						
Vegetation	River cooba	*Acacia stenophylla*		Known	Known	Yes						
Vegetation	Nitre goosefoot	*Chenopodium nitrariaceum*		Known	Known	Yes						

Appendix 2: Lachlan asset/WMA delivery descriptions

Asset: Lachlan River channel

Environmental water could be used to contribute to baseflows and provide freshes to the Lachlan River channel, to support longitudinal and lateral connectivity, habitat values and healthy ecosystem function.

Water Management Area: Wyangala Dam to Jemalong Weir

Murray cod, golden perch and the newly stocked olive perchlet are important fish species in this section of the river. Important considerations for this WMA will be the maintenance of fish habitat and relevant flows under extreme-dry-to-dry conditions, when dam releases are restricted for town water supply purposes.

Also weir drownout to improve fish passage under median and wet conditions will be important. Cottons Weir at Forbes is the main barrier (as there is no fishway) and it requires 9,250 ML/d for drownout to occur.

Water Management Area: Jemalong Weir to Lake Cargelligo (includes Goobang Creek)

Murray cod and golden perch are again important fish species in this section of the river. Important considerations for this WMA will be the maintenance of fish habitat and relevant flows under extreme-dry-to-dry conditions, when dam releases are restricted for town water supply purposes.

For fish passage, Condobolin Weir requires 4,100 ML/d and West Condobolin Weir requires 3,800 ML/d for drownout. Jemalong Weir is a gated structure and, for significant periods of time, the gates are lifted and therefore provide some fish passage.

Water Management Area: Lake Cargelligo to Lake Brewster

This section of the river and also to the Great Cumbung Swamp generally has permanent water supplies. However, during the recent critical water-shortage, flows to this part of the river and further downstream were severely restricted. In such circumastances, refuge pools are at risk of drying out and poor water-quality conditions may develop (e.g. stratification), putting aquatic life at risk. These circumstances are particularly notable at weir pools which generally provide permanent water such as Lake Cargelligo Weir and those downstream.

Weir drownout for fish passage is not such a consideration for this section of the river as fishway construction is underway at Cargelligo Weir.

Water Management Area: Lake Brewster to Great Cumbung Swamp

As above, regarding flow and water-quality considerations for refuge pools.

Weir drownout to improve fish passage is a major consideration for this section of the river because of the number of weirs and the progressive reduction in flows. Fishway construction is underway on Booligal Weir. Willandra Weir requires some 8,500 ML/d and Hillston Weir requires 4,750 ML/d for drownout (both are fixed crested). However, Brewster Weir is the main barrier (for the entire Lachlan River) with drownout requiring flows in excess of 15,000 ML/d.

Asset: Burrawang West Lagoon

Burrawang West Lagoon is a small wetland (21 hectares) located near the junction of Goobang and Yarrabandai Creeks, about 20 kilometres east of Condobolin. Water levels within the creek system and in the lagoon are maintained by a weir on the junction of Goobang and Yarrabandai Creeks, which was constructed in the 1890s. This resulted in a wetland which was almost permanently inundated, and the development of habitats that support a wide variety of wetland-dependent species.

The site consists of a 30 metre-long channel acting as a control weir maintaining water levels in the lagoon, inlet channel, Yarrabandai Creek and an extensive length of Goobang Creek. Flows are diverted from Bumbuggan Creek into the inlet channel through a 230 millimetre-diameter pipe. Other natural inflows occur from run-off.

A draft Burrawang West Lagoon Management Plan has recently been completed and addresses water management and accounting issues that have arisen at this site (LCMA 2011).

Asset: Yarnel Lagoon

The lagoon is directly connected to Wallaroi Creek on its north-west side. The creek is the most southerly of the anabranching creeks in the middle reaches of the Lachlan River. It is generally narrow and shallow. The flow travelling down Wallaroi Creek is first diverted out of the Lachlan River into Island Creek, from Island Creek into Wallamundry Creek, and out of Wallamundry Creek into Wallaroi Creek, eventually reaching Yarnel Lagoon close to the end of Wallaroi Creek.

The NSW Office of Environment and Heritage is developing a management plan for this lagoon which addresses water requirements to achieve ecological outcomes, particularly with regard to supporting frog breeding (OEH, in prep.).

Asset: Booberoi Creek

The Booberoi Weir was built in 1902 to divert flows down Booberoi Creek for stock and domestic use and some irrigation flows. The creek, an anabranch of the Lachlan, leaves the river halfway between Condobolin and Lake Cargelligo and rejoins downstream of Lake Cargelligo. The creek is regulated for stock and domestic supply along its length. The WSP provides up to 12,500 megalitres for replenishment flows each year, with a target of maintaining visible flow at Ginniguldrie Road bridge. The current supply is nearly a continuous flow when the water is available. In extreme dry circumstances, as in the recent drought, this water is not provided. State Water advise that a flow of 4,000 megalitres will reach the end of the system. It is not possible to provide higher flow diversions into Booberoi Creek without incurring large losses, as the channel near the regulator is highly silted.

Anecdotal evidence from local anglers and landholders indicate that fish species including freshwater catfish, golden and silver perch, and Murray cod occur in the area. The creek supports sections of native riparian and aquatic vegetation and is considered to contain important ecological features.

Asset: Lake Brewster

Lake Brewster is located downstream of Mountain Creek on the southern side of the Lachlan River. Originally the lake would have only flooded during very large flood events, where flows would have travelled down Mountain Creek and across the floodplain. To capture flows from the upper Lachlan and re-regulate flows to the lower Lachlan, a large weir and channels to and from the Lachlan River were constructed in the 1950s. The length of the Lachlan and the distance from Wyangala Dam makes Lake Brewster an important structure for delivering water to the lower Lachlan and its wetlands.

The lake receives water via an inflow channel from the Brewster Weir and water is stored until required for downstream use. This operation has resulted in increased frequency and length of inundation. Originally a dead storage area of about 20,000 megalitres remained in the deepest part of the lake, which was unable to be released. The lake has recently been modified with the objectives of improving water efficiency by reducing the dead storage, and improving water quality and ecological health. Following the modifications, Lake Brewster can now store approximately 105,000 megalitres with minimal dead storage. To improve water quality the lake has been divided to form an inflow wetland (1,500 megalitres), which receives flows via the inlet channel and delivers them to the main storage area. To further improve water quality, water released from the main storage area (98,000 megalitres) can travel via three outflow wetlands (5,000 megalitres) to the outlet channel. Alternatively, this water may be released directly to the Lachlan River via the outlet channel.

The inlet regulator has a maximum capacity of 6,000 ML/d. The outlet regulator has a maximum planned capacity of 2,000 ML/d. As part of the reconfiguration of the lake, water passes through inflow and outflow wetlands to improve the quality of water entering and leaving the lake. Water retention times in these wetlands are dependent to some extent on water quality, e.g. fill rates of inflow wetland vary from six hours to three days.

Lake Brewster is operated to receive operational surpluses, unregulated tributary flows and Wyangala Dam spills. Up until 2000, inflows were regularly stored in the lake in winter and spring and released for downstream use in late spring and summer. This was likely to occur approximately eight out of 10 years prior to 2000. Due to drought conditions, since 2000 the lake had only received one small inflow in 2005, which sparked a bird breeding event. Flows during the spring of 2010 resulted in the lake being filled to 75 per cent, but the lake was not completely filled due to a pelican breeding event.

The lake has major importance for the management of environmental water because it can hold large volumes of environmental water allocations. Under the Water Sharing Plan, the lake can hold a reserve of 10,000 megalitres for environmental purposes under certain conditions. As part of the water efficiency works, a general security environmental water entitlement of 12,000 megalitres was created from the water savings and is subject to a draft Water Use Plan. The draft Water Use Plan makes 12,000 megalitres available for use in the Lake Brewster constructed wetlands, in order to enhance opportunities for threatened and other native fish and waterbirds in the lake and the lower Lachlan, and to enhance river and wetland habitat in Lake Brewster and the lower Lachlan.

The release capacities from the lake and Brewster Weir are very important for downstream water orders. Lake Brewster, in conjunction with the conduit for Brewster Weir, previously had a release capacity of 3,500 ML/d. The current arrangements for releases are between 1,800 and 3,000 ML/d as per the following:

- 1,200 ML/d via Brewster Weir conduit
- 600–1,800 ML/d via the lake depending on storage capacity.

Water Management Area: inflow wetland

The Lake Brewster inflow wetland is 300 hectares and requires 1,500 megalitres to fill. Filling occurs via a regulator and channel extending from Lake Brewster Weir on the Lachlan River. The wetland was originally part of the larger area of Lake Brewster but a block bank has been constructed to retain water in this area for longer periods. The main objective for the retention of water within this area is to improve water quality by promoting aquatic plant growth and consequently to act as a refuge for wetland-dependent species. To date, aquatic plant growth within the inflow wetland has responded well to inundation, which first occurred in September 2010.

Water Management Area: outflow wetland

The outflow wetland is comprised of a series of cells. The eastern side of the wetland is divided into two areas. The first (cell 1) covers an area of approximately 180 hectares, which when full, hold water at an average depth of approximately 0.4 metres (850 megalitres). The second area (cell 2) on the eastern side covers another 120 hectares. Once the first cell is full it will overflow into this second area. When both cells 1 and 2 are full they will store 300 hectares at an average depth of 0.4 metres (1,200 megalitres). The third area of the outflow wetland (cell 3) is located on the western side and covers an area of approximately 300 hectares and will store another 1,200 megalitres when full. An additional area of approximately 1,100 hectares lies to the north of the outflow wetlands; this area will generally hold water when the Lake Brewster storage holds more than 98,000 megalitres.

There is a preliminary design report for the operation of the outflow wetland (GHD 2005) which indicates that a retention time of five to six days is required for water quality improvement to be achieved. As retention times increase, the release capacity is reduced.

Water may also be passed into the outflow wetland to meet ecological requirements under two scenarios:

1. as part of a release that would otherwise be discharged directly via outlet channels, or
2. independent of any release, where the ecological requirement in the wetland does not coincide with normal release operations.

Where water is passed through the wetlands under scenario 1, any additional losses incurred as a result of wetland operations may be debited from the 12,000 megalitres of water savings environmental allocation. Alternatively, if the wetland requirements are in alignment with prescribed uses for the 10,000 megalitres Lake Brewster ECA, the volume may be debited from the ECA account. Under scenario 2, where water is released solely for the wetlands, the full volume passed into the wetlands may be debited from either the 12,000 megalitres or the 10,000 megalitres ECA account.

Following inundation at the end of 2010, a large pelican colony began breeding, nesting on the outlet channel banks and outflow wetland banks. The first batch of chicks hatched in December 2010, with breeding continuing until May 2011. This event became the largest pelican breeding to occur in NSW for at least five years (P Packard (OEH) 2010, pers. comm.). The presence of the pelican nests has affected the operation of the storage, as the water level in the outflow wetland was required to remain relatively stable and the opportunity to store further unregulated tributary flows was lost. Accounting for the loss in storage opportunity is to be resolved but is likely to involve an offset from planned environmental water, Lake Brewster environmental water savings and some contribution from consumptive licence holders.

Asset: Willandra Creek

Willandra Creek is a major distributary (effluent) creek which leaves the Lachlan River upstream of Hillston. It runs many kilometres to the west, now terminating in Gunaramby Swamp. In prior wetter times the creek terminated in the Willandra Lakes. Flows to the creek are controlled by Willandra Weir and the nearby regulator for the creek. Willandra Creek offtake is an excavated channel constructed in 1891, which is at a much lower commence-to-flow than the natural channel (see below).

The upstream portion of the creek receives regulated flows from the Lachlan River for irrigation and stock and domestic purposes. The regulated section finishes at the Willandra National Park 'Homestead' Weir. The maximum allocation allowed for extraction from the creek is 23,457 megalitres (DIPNR 2003).

The Water Sharing Plan provides for a 12,000 ML/yr replenishment flow. The downstream target for this flow is the Balranald/Ivanhoe Road west of Morrison's Lake.

There are important environmental assets along the creek, including:

- the creek itself
- Willandra National Park—which is substantially a terrestrial park with a significant creek frontage
- Morrison's Lake—which is a nature reserve
- Gunnaramby Swamp at the end of the creek—this site is not considered in this document as it only receives large floods.

Hydrological modelling (Hameed et al. 2005) has demonstrated that Willandra Creek under current conditions takes a much greater share of water than it did under pre-development conditions, and this effect is noticeable in flow changes at Oxley.

Water Management Area: Willandra Creek reaches

Love (1999) divided Willandra Creek into four reaches based on riparian vegetation and channel structure. The following descriptions are provided by Love (1999):

- Natural offtake—this is the original natural channel for the creek which starts some 2 kilometres upstream from Willandra Weir. The channel meanders for several kilometres but only flows when the river reaches the commence-to-fill of some 8,000 ML/d at Willandra Weir. The channel is deep with considerable woody debris. Riparian vegetation is dominated by river red gum and river cooba.
- The cutting—this is the excavated channel which cuts off the natural offtake channel. It runs some 16 kilometres to join the creek. It has a more trapezoidal channel shape and there is little riparian vegetation with less dense stands of river red gum and river cooba.
- Upper reach—this reach runs to the Cobb Highway beyond Willandra National Park. It is a well defined channel with riparian vegetation dominated by black box and river cooba.
- Lower reach—Cobb Highway to Gunnaramby Swamp. This creek channel is less well defined, particularly proceeding further west. Riparian vegetation is dominated by lignum.

There have been no systematic ecological studies of the Willandra Creek system to provide more information on water management of these areas. Therefore the following information is based on very limited information.

Water Management Area: Morrison's Lake

Morrison's Lake is about 300 hectares in size and is a nature reserve located on the downstream reach of Willandra Creek. The lake was previously part of the Ivanhoe Town water supply with water being provided via Willandra Creek as part of the 12,000 ML/yr replenishment flow. When Willandra Creek is filled, water can be directed into the lake via regulators. Morrison's Lake is now not part of the town water supply as it has been replaced by a 350-megalitre concrete storage.

During the recent drought there were supply constraints in providing water to Ivanhoe because of the low water levels in Wyangala Dam. Consequently a commitment has been made to provide Ivanhoe with alternative water via groundwater bores. The effect these arrangements will have on the water regime of Morrison's Lake is yet to be investigated, and it is understood that the NSW Office of Environment and Heritage is preparing a management plan for the lake.

Water delivery to the lake is achieved with a flow target of 150 ML/d at Willandra Homestead Weir with flows taking up to 90 days to reach the lake. The volume-to-fill for the lake is estimated at between 1,560–3,700 megalitres depending on antecedent conditions. State Water has advised a volume-to-fill of 4,000 megalitres.

Asset: Merrowie Creek

Merrowie (aka Marrowie) Creek is an effluent distributary which leaves the Lachlan River just upstream of Hillston. It is an extremely long creek, along with its conjoined Box Creek which starts downstream of Lake Tarwong. Box Creek runs north and then west of the Great Cumbung Swamp and eventually joins the Murrumbidgee River.

Cuba Dam and Lake Tarwong to Chilchil Swamp are nationally important wetland sites along the creek.

The Lachlan Water Sharing Plan makes provision for an annual stock and domestic replenishment flow of up to 9,000 megalitres for the Merrowie Creek Water Trust area. Water for the replenishment is provided by unregulated flows when possible and by storage releases when these flows do not occur. The replenishment fills the weir pools along the creek with Cuba Dam being the terminus of the trust area. Gonowlia Weir is used to divert this water from the Lachlan into the creek. The creek also has a regulator near its source to exclude other flows if necessary.

There are 14 licenced weirs along the creek. The replenishments are provided at about 150–200 ML/d for about 6–8 weeks to reach Cuba Dam, generally in the late autumn to winter period. Flows above this level will result in the Box Creek (see below) Regulator being overtopped. Therefore, under these conditions, there is no freeboard (which refers to the vertical distance between the water level and the top of the structure) in the creek and piggybacking using environmental water would need to be done by extending the duration of the replenishment flow.

Box Creek leaves Merrowie Creek some 60 kilometres downstream of the offtake from the Lachlan River. Some flows in Box Creek can be controlled by a regulator. Flows down Box Creek enter Merrimajeel Creek just upstream of the Booligal Swamp.

Other flows, mostly unregulated, enter Merrowie Creek when the flows are in excess of 2,500 ML/d. It is these flows which can extend beyond Cuba Dam, reaching the Tarwong Lake and Swamp system and beyond, depending on the size of the flood event. Beyond Lake Tarwong, water flows into (another) Box Creek and onto Chilichil Swamp, but only in large flood events.

Water Management Area: Merrowie offtake to Toms Lake

The upper Merrowie Creek area supports valuable riparian vegetation, particularly lignum. The creek also delivers water to a number of ecologically valuable weir pools, such as Mutherumbung which has provided nesting sites for colonial waterbirds, and Toms Lake which supports a variety of waterbirds including the blue-billed and freckled ducks. The weirs along the creek are all drop board structures and the boards are removed during the replenishment flow, which provides connectivity along the creek and with the Lachlan River for 6–8 weeks. Cuba Dam also has drop boards but is drowned out at 400 ML/d (a large flow for this site).

Water Management Area: Toms Lake Weir pool

Toms Lake Weir pool is located towards the downstream end of the Merrowie Creek Water Trust area and receives stock and domestic replenishment flows. In 2005, water was released from the weir pool by the landholder and Water Trust to provide top-up water for the waterbird breeding event at Mutherumbung Weir (see below).

The riparian vegetation surrounding the weir pool is dominated by river red gum, black box, river cooba and cooba. The pool appears to extend about 4 kilometres in a direct line upstream of the weir, but the channel is meandering so a larger area would be inundated when full. The volume-to-fill requirement are not known.

Water Management Area: Mutherumbung Weir pool

Mutherumbung Weir pool is located towards the downstream end of the Merrowie Creek Water Trust area and received the 2005 stock and domestic replenishment flow. The riparian vegetation along the weir pool is dominated by lignum with scattered black box, river cooba and cooba.

In November 2005, 8,000–10,000 ibis pairs were found breeding on the weir pool. This event provides information about water management for this site at this time of the year. The stock and domestic replenishment flow to the area had ceased but evaporation was high and the water level in the weir pool was dropping. Actions taken to maintain the water level included:

- the landholder delayed pumping from the weir pool, which was intended for stock purposes around the property
- a release of water from Toms Lake Weir pool was organised, because the travel time for water to reach the site from the Lachlan River would have resulted in the water reaching Mutherumbung too late
- a 'replacement' diversion from the Lachlan River to Toms Lake and Mutherumbung was commenced—a release of 117 ML/d commenced on 8 December 2005 and was completed on 4 January 2006 with a total of 5,532 megalitres provided.

Water Management Area: Cuba Dam Weir pool

Cuba Dam Weir pool is located at the end of the Merrowie Creek Water Trust area and receives stock and domestic replenishment flows. The dam was constructed in the mid-1880s by James Tyson to provide stock water.

The dam fills in four to five weeks under uncontrolled flow conditions (1,500 ML/d or more at Hillston) or in 6–7 weeks under controlled replenishment flows of 200 megalitres. The volume-to-fill is approximately 800 megalitres (Barma et al. 2010).

The riparian vegetation surrounding the weir pool is dominated by lignum. The site has provided for several large colonial waterbird breeding events including in 1984, 1989, 1990 (Whitehead & McAuliffe 1993). Some 40 species of waterbirds and nearly 50,000 breeding ibis were recorded by Magrath (1992) in 1990.

In 2010, a replenishment flow, supported by environmental flow releases which were used to enable flooding all the way to Cuba Dam, sparked a waterbird breeding event. On 3 November 2010 it was confirmed that inundation at Cuba Dam had triggered colonial nesting of straw necked ibis (approximately 500 pairs) 2.5 kilometres upstream of the dam. Subsequent observations on the ground indicated that the colony was actively expanding. Analysis of high-resolution digital vertical photography captured more than 10,000 nests in the area on 12 December 2010.

The aim of the second phase of environmental watering was to deliver 3,000 megalitres to Merrowie Creek at 120 ML/d to support the completion of the bird breeding event and to inundate Lake Tarwong. Environmental water flows into Merrowie Creek commenced on 16 November 2010 and concluded on 13 December. The head of the environmental flow arrived at Tarwong on 26 December 2010. The total volume of environmental water delivered was 3,000 megalitres.

Water Management Area: Lake Tarwong system

Merrowie Creek is approximately 135 kilometres long and terminates into the Lake Tarwong swamp system. At about 25–30 kilometres upstream (below Cuba Dam), the channel braids into the wider floodplain. When the lake is full, backwater flows into swamps upstream. Backflow first goes to the southern swamp and then into the more open northern swamp.

When the lake fills, water also flows into Box Creek downstream. There is a licenced regulator at the exit from the Lake to Box Creek.

The lake filled in 2010 from local rainfall, replenishment and environmental flows (see Cuba Dam description for details) with 3,830 megalitres of environmental water delivered to Merrowie Creek in 2010. Prior to this the lake was last filled in 2000 (this was the 350,000-megalitre translucency flow event) and just started to run into Box Creek but with no flow into the upstream swamps. The 1996 and 1998 flood events filled the lake and associated swamps.

State Water advises that about 2,000 megalitres is required to get water from Cuba Dam to Lake Tarwong. Based on their sizes and antecedent conditions, the volume-to-fill estimates are:

- Lake: 150 hectares = 750–1,800 megalitres
- South swamp: 150 hectares = 750–1,800 megalitres
- North swamp: 400 hectares = 2,000–4,800 megalitres.

Asset: Moon Moon Swamp

Moon Moon Lake/Swamp is adjacent to the Lachlan River about 30 kilometres upstream by road from Booligal. A part of the swamp was previously the Moon Moon State Forest and is now part of the Riverina Red Gum Forests National Park (the actual area of the park is to be established). Inflows to the swamp occur from two channels from the Lachlan River, with the most easterly channel being the main carrier. The swamp is some 300 hectares and part of a larger floodplain of some 8,000 hectares. In larger floods, water spills past the swamp into a lignum dominated depression that has been reported to support ibis breeding and likely other species. Only the 300-hectare area is considered in this document.

The following water management information is from BWR (2010):

- travel time from Wyangala Dam is about 37 days, and 17 days from Lake Brewster
- CTF is around 2,000 ML/d at Whealbah
- estimated volume-to-fill for the 'critical area' of 210 hectares of the lake is between 1,050 megalitres and 2,520 megalitres depending on antecedent conditions.

As an indication of what would be required to deliver environmental water to Moon Moon, the following information is provided on the February–March 2010 unregulated flow event. This event reached the CTF for Moon Moon and some water filled the lower parts of the swamp (P Packard (OEH) 2011, pers. comm.) but the extent of flooding has not been determined:

- the combined flow at Willandra Weir and regulator was some 26,100 megalitres between February 21 and March 12 (includes flows above 200 ML/d)—the maximum discharge reached 2,869 ML/d at the weir with a maximum of some 100 ML/d down Willandra Creek
- the flow at Hillston Weir reached 2,170 ML/d and therefore some water may have passed into Middle Creek
- over the 30 days associated with the event, some 25,000 megalitres passed Whealbah gauge with a maximum of 2,200–2,300 ML/d for five days.

In 2010, further flow events have occurred in the Lachlan, and analysis of these and earlier events, and the extent of flood inundation of Moon Moon using remote sensing sources, is proposed to better establish environmental water delivery requirements.

Asset: Booligal Wetland system

The Booligal Wetland system consists of four WMAs: Murrumbidgil Swamp, Merrimajeel Swamp, Booligal Swamp and Lower Gum Swamp. The hydrology of this system is amongst the best known of all the assets covered by this document.

The Booligal Wetland system receives water from Torriganny Creek which is an anabranch of the Lachlan River. The Creek carries about 66 per cent of the total river flow. Muggabah and Merrimajeel Creeks are natural effluents from Torriganny Creek and provide the water to the wetland system.

Muggabah and Merrimajeel Creeks are part of a longstanding Stock and Domestic Water Trust. The replenishment under the Water Sharing Plan is up to 9,000 ML/yr and can be provided from unregulated flows in the river or releases from upstream storages. Recent replenishments of about 7,000 megalitres were provided during the severe drought (BWR 2010). Water for stock and domestic purposes are diverted into the creeks via Torriganny Weir generally in the colder months. Torriganny Weir is on Torriganny Creek and there are also new regulators on Merrimajeel and Muggabah Creeks. Generally the stock and domestic replenishment is delivered at around 100 ML/d. Murrumbidgil Swamp is the downstream target for the stock and domestic replenishment on Merrimajeel Creek and 'Little Lake' on the Muggabah.

The Booligal system is known to flood extensively when flows exceed 2,500 ML/d over 30 days or more, measured at Booligal Weir gauge. An example is the 1984 flood where flow at Booligal Weir was 3,000 ML/d for some 75 days, with flows of 500 ML/d into Merrimajeel Creek and 300 ML/d into Muggabah Creek over this period (or a total of 37,500 megalitres and 22,500 megalitres respectively) (Wettin & Bennett 1988).

Dwyer and Bennett (1988) provide a detailed assessment of the results of intentional diversion of flows into this system during the 1986 unregulated flow event. Of the 235,000 megalitres passing Willandra Weir, some 20,000 megalitres entered the creek system with some 3,500 hectares flooded. There was no waterbird breeding created by this event.

Water Management Area: Booligal Swamp

The Booligal Swamp (aka 'block bank') is widely known as a site for major waterbird breeding events during flooding. Since the 1980s, bird breeding events have occurred in 1984, 1989, 1990, 1992, 1993, 1996, 1998 and 2000 (Driver et al. 2005, 2010). The site has been the target for environmental water management/releases on all occasions since 1984 to allow for the completion of waterbird breeding. A temporary block bank was constructed in 1984 to assist in holding and stabilising water levels beneath colonial nesting birds to prevent abandonment by adults. This bank was replaced by a larger, more permanent structure with a drop board regulator in 1992, which was positioned in a more downstream location. The block bank has been used in all waterbird breeding events since 1984, in conjunction with environmental water diversions from Torriganny Weir. The translucency flow event in 2000 resulted in significant waterbird breeding.

As indicated above, Dwyer and Bennett (1988) identified that large volumes of water are required to create significant flooding of the Booligal Swamp area. All major flooding of the area and waterbird breeding events have been the result of natural flooding events.

Driver et al. (2005, 2010) have undertaken an analysis of waterbird breeding events and correlated the events with the hydrology of the Booligal system. Based on this work the threshold for waterbird breeding to commence is 2,500 ML/d at Booligal Weir. Significant breeding events occur when this flow exceeds 60 days (or a total of 150,000 megalitres), but with a minimum duration of 19 days for a small breeding event in 1996 (a total of 47,500 megalitres). The 1996 event is the smallest flood with a recorded breeding event and could be considered as a threshold event.

Diversions to the swamp to support waterbird breeding have been at a rate of around 50 ML/d, with the releases originating from Lake Brewster and taking about 18 days' travel time to Torriganny Weir and three days from the weir to the breeding area. Volumes of water used to support these events have varied between up to 11,500 megalitres in 1992–93, and 650–3,800 megalitres for more recent events (e.g. 2,080 megalitres in 2000–01 after the 350,000 megalitre translucency event).

In 2010, a waterbird breeding event at Booligal was triggered by local rainfall and a managed stock and domestic replenishment flow in the Merrimajeel Creek. On 21 October 2010, preliminary stages of a breeding event were observed in the Lachlan Valley State Conservation Area (Booligal Station) involving more than 15,000 straw-necked ibis. Small numbers of glossy ibis were also observed congregating on the Merrimajeel Creek upstream of the main colony. Following the conclusion of the replenishment flow, intervention was required to prevent the water levels at the colony site receding rapidly which would likely lead to abandonment of nests and failure of the breeding event. Environmental water was ordered to support the event. To maintain water levels at the site prior to arrival of the environmental water from Lake Brewster, and subsequently during the breeding event, it was necessary to install and adjust boards in the block bank regulator.

Environmental water was delivered for 59 days at an average rate of 40 ML/d (approximately 2,360 megalitres) to support the event.

Water Management Area: Murrumbidgil Swamp

Murrumbidgil Swamp (locally known as Angora Clump) is located at 'Woorandarah' on Merrimajeel Creek, about 40 kilometres from Torriganny Creek which is its water source. Prior to regulation, the site flooded seasonally forming a river red gum, river cooba, cooba, black box and western grey box wetland association. In November 2010, the swamp filled following the combined inputs of local rainfall, replenishment and environmental flows.

The swamp is the downstream target for the annual stock and domestic replenishment for Merrimajeel Creek as part of the Muggabah and Merrimajeel Creeks Water Trust. The replenishment is generally provided during the cooler late autumn to early spring months for delivery efficiency reasons. Flows in warmer months result in plant growth in the creek channel, which inhibits water passage and prevents water from reaching the swamp.

The following water supply information is from BWR (2010):

- Stock and domestic flows in the Merrimajeel Creek channel are delivered at a rate of about 60 ML/d. Channel flow capacity is about 100 ML/d before water starts to break out. This equates to approximately a 40 ML/d freeboard.
- Travel time is about 70 days from Torriganny Weir, which equates to about 4,000 megalitres total flow reaching the swamp.
- The CTF for Merrimajeel Creek, with no boards in Torriganny Weir, is about 250 ML/d. Water reaching the swamp is dependent on the duration of these flows due to its distance from the water source. Hydrology modelling by Barma et al. (2010) has indicated that Murrumbidgil Swamp has a CTF level of 1,560 ML/d at Booligal gauge.
- The volume-to-fill is estimated to be between 600 megalitres (wet conditions) and 1,400 megalitres (dry conditions).
- Based on the 600–1,400 megalitres volume-to-fill, a release at Torriganny Weir of 4,600–5,400 megalitres into Merrimajeel Creek is required. The 600–1,400 megalitres can be provided 'on top' of the stock and domestic replenishment as there is about a 40 ML/d freeboard in the creek channel. The release would be required for about 15–35 days to fill the swamp.

Water Management Area: Lake Merrimajeel

Lake Merrimajeel is located at 'Woorandarah' on Merrimajeel Creek, about 42 kilometres from Torriganny Creek, its water source. The site is intermittently flooded, with lignum and nitre goosefoot the dominant vegetation. The lake is just downstream from Murrumbidgil Swamp, which is the downstream target for the annual stock and domestic replenishment for Merrimajeel Creek. The lake received flows in November 2010 following local rainfall, replenishment and environmental flows.

Much of the hydrological description provided above for Murrumbidgil Swamp applies here with the following additional information:

- Hydrology modelling by Barma et al. (2010) determined the volume-to-fill to be 500 megalitres. However, BWR (2010) estimated a volume-to-fill of between 500 megalitres (wet conditions) and 1,200 megalitres (dry conditions).
- Based on a volume-to-fill of 600–1,200 megalitres for the lake, a total release of some 5,600–6,660 megalitres into Merrimajeel Creek would be required which is inclusive of the stock and domestic, and Murrumbidgil Swamp filling. This water can be provided 'on top' of the stock and domestic replenishment as there is about a 40 ML/d freeboard in the creek channel (BWR 2010). The release would be required for about 12–30 days to fill the lake after the swamp has filled.

Water Management Area: Lower Gum Swamp

Lower Gum Swamp is on Muggabah Creek, about 6 kilometres west of the Booligal township and some 20 kilometres from Torriganny Weir via the creek channel. Muggabah Creek also receives stock and domestic replenishment flows and the delivery of this water extends well downstream of Lower Gum Swamp to 'Little Lake'. Lower Gum Swamp is not inundated by stock and domestic flow.

The control sill for the flows into the swamp is at the southern end, adjacent to the creek channel. Higher (but undetermined) creek flows are required to fill the swamp and some of the water drains from the swamp once creek flows decrease.

Barma et al. (2010) provides the following information:

- travel time to the swamp estimated to be 30–40 days from Torriganny Weir
- a volume-to-fill of 160–384 megalitres based on wet to dry antecedent conditions
- piggybacking on the stock and domestic replenishment is possible and likely the most efficient way to conjunctively provide the water—the CTF information is needed to confirm this option.

Asset: Lachlan Swamp System

The Lachlan Swamps floodplain area (and some high country) on the northwest bank of the river covers about 10,000 hectares (Barma et al. 2010). There is a similar area of floodplain on the south-east bank (Barma et al. 2010).

The Lachlan Swamp system has been divided into four WMAs: Lake Waljeers, Peppermint Swamp, Lake Bullogal and Ryans Lake. The latter two sites are not covered in this document as they are only inundated during flood events.

The swamp system receives flow primarily from the Lachlan River. Infrequently, water can also enter the system from Mirrool Creek which joins the Lachlan (after passing through the Murrumbidgee Irrigation Area) adjacent to Lake Waljeers, and from Muggabah Creek which enters near the Peppermint Swamp area.

Lake Waljeers is the first asset to receive water from the Lachlan River, while Peppermint Swamp is the second asset within the Lachlan Swamp to receive water. Barma et al. (2010) identifies that the floodplain upstream of Lake Waljeers requires 19,000–50,000 megalitres to flood. The floodplain downstream of the lake requires 20,000–35,000 megalitres.

The following information is provided in Barma et al. (2010), as a general indication of how this system responds to river flows and as a guide on a possible environmental water release. It is based on the spring 1995 unregulated flow event in August and September:

- On 15 August, water reached Lake Waljeers. Travel time from the river was three to four days.
- Water flows through creeks to the north of the lake. These creeks supply the lake and also bypass the lake toward Peppermint Swamp.
- On 5 September water reached Peppermint Swamp.
- Flow south-west from the lake is blocked by a levee bank around the south-west margin of the lake. This levee was constructed in 1967. Prior to 1967, the floodplain downstream of the lake would be flooded. There are gates in the levee but they have been kept closed.
- Total flow in August for this event was some 20,000 megalitres at Booligal with a peak flow of 1,200 ML/d.
- Water in the 1995 event did not reach Lake Bullogal or Ryans Lake. They only receive water in large floods, e.g. 1984, 1989, 1990.

The MDBA (2010) also provides information on the characteristics and hydrology for this area. It is notable that the MDBA report also includes Lake Ita, Baconian Swamp and floodplains in its Lachlan Swamps assessment.

There is considerable potential for piggybacking, but these arrangements have not been fully investigated for this area.

Water Management Area: Lake Waljeers

Receiving flows in November 2010, the lake is about 520 hectares and consists of an open water area with a margin of largely river red gum. The following information is from Barma et al. (2010) unless otherwise cited:

- travel time is about five to seven days from Booligal Weir
- CTF point is about 5–6 kilometres upstream of the lake, with another breakout from the river about 2 kilometres upstream
- CTF from Barma et al. (2010) is 800–1,200 ML/d for the upper Lachlan swamp floodplain and Lake Waljeers. MDBA (2010) used 850 ML/d
- the volume-to-fill identified from Barma et al. (2010) is 5,000–10,000 megalitres; an alternative estimate, which assumes 5–12 megalitres per hectare, is a volume-to-fill of 2,600–6,240 megalitres
- depth of the lake is about 2.5 metres at maximum flooding. As inflows cease, water drains into the channels to the north that supply the Peppermint Swamp area. Final lake depth is about 1.5 metres. The lake holds water for 18 months assuming no further inflows.

Water Management Area: Peppermint Swamp

The swamp is about 120 hectares in area. According to Barma et al. (2010) the CTF is between 950 ML/d and 1,350 ML/d at Booligal Weir. The volume-to-fill is identified as 400 megalitres, or alternatively 600–1,440 megalitres if 5–12 megalitres per hectare is assumed (Barma et al. 2010).

Asset: Ita Lake

Ita Lake covers about 1,200 hectares and is located on the Kalyarr State Conservation Area (previously the property 'Norwood') some 20 kilometres upstream of Oxley. Located in Kalyarr State Conservation Area and part of the nationally significant Lachlan Swamp complex, Lake Ita has important cultural and ecological values. It is a wetland typical of many fed by the lower Lachlan during medium-to-high flows, big enough to sustain significant ecological values and small enough to respond to the volumes that licenced environmental water can deliver. There is substantial evidence of Aboriginal cultural relationships that will serve as a benchmark for assessing restoration potential of a moderately degraded wetland. It may also provide a comparison of the relative condition between wetlands, with those close to natural versus those with altered flow regimes. However, the infrastructure does not support efficient watering at present.

The lake bed is south of the Lachlan and set back from the river by about 3 kilometres. A series of inflow channels from the river feed into a main supply channel which flows into the north-west part of the lake. These channels cover a large area and it is likely they absorb considerable water before flows reach the lake bed. A regulator[4] was located on the main inflow channel near the head of the lake. This regulator appears to have been constructed in 1976 and could have been used to influence inflows, and therefore the results for the individual flood events, satellite image analysis and hydrology results of BWR (2010) below.

Pimpara Creek, a high-level effluent of the Lachlan, runs adjacent to the south end of the lake to join the Murrumbidgee River. This creek only flows when there is large flooding of either the Lachlan or Murrumbidgee Rivers (via backwater).

The following is based on BWR (2010):

- CTF is currently estimated at 1,800–2,000 ML/d at Corrong—this is a very high flow for this section of the river
- the volume-to-fill for the entire lake, based on the wet to dry antecedent condition estimates (i.e. 5–12 megalitres per hectare), is between 6,000 megalitres and 14,400 megalitres—smaller volumes will fill portions of the lake
- travel time from Wyangala to Corrong is about 75 days, travel time from Lake Brewster to Corrong is about 55 days, and Ita lake would be several days of travel time past the Corrong gauge. The Lachlan catchment has an extremely low gradient in this section of the river.

Based on the above, BWR (2010) concluded that a specific environmental water release to Ita lake is an unrealistic option. The lake CTF of 2,000 ML/d at Corrong requires a flow of some 12,000 ML/d at Brewster Weir (S Sritharan 2011, pers. comm.) and this flow cannot be achieved with combined Lake Brewster, Lake Cargelligo and Wyangala Dam maximum releases without causing flooding conditions to sections of regulated upper and mid-Lachlan River.

However, during the high flows experienced in the lower river in January 2011, some water entered the lake via the north-west channel representing a much lower CTF for the lake of around 650 ML/d at Corrong. This was the first high river flow experienced following removal of the unapproved regulator on the inflow channel which had been acting to prevent or restrict river flows from entering the lake (P Packard (OEH) 2011, pers. comm.). Therefore it may be possible to deliver some environmental water into the lake, particularly through piggybacking onto other flows in the system.

In 2010–11, flows were found to enter Lake Ita from the river following removal of the inflow regulator, and from localised storm events providing flows to Pimpara Creek. There were some local observations which suggested that water in Lake Ita returned to the river via the inlet channel once river levels had dropped (and with no regulator to contain this water). The extent of inundation and the volume of water entering and leaving the lake is currently unknown.

4 It is has been reported that this regulator has been removed in recent months.

Asset: Baconian Swamp

The swamp is located just upstream of Oxley on the property 'Tupra' and is dominated by river red gum with a margin of black box trees. The swamp is about 800 hectares but is associated with a broader floodplain (see BWR 2010). There are two natural offtake channels from the river to the swamp—the most easterly passes near the 'Tupra' homestead and the western channel leaves the river near the Oxley road bridge. This latter offtake is the main water carrier; its bed has been lowered by a channel constructed in the early days of pastoral development. Oxley State Forest covers at least part of the swamp and is now part of the Riverina River Red Gum Forests National Park.

The following water delivery information is from BWR (2010):

- travel time is 90 days from Wyangala Dam and nearly 70 days from Lake Brewster
- CTF is 350 ML/d at Tupra gauge, based on a 2005 unregulated event which delivered water to the swamp
- the volume-to-fill for the swamp, based on the wet to dry antecedent condition estimates (i.e. 5–12 megalitres per hectare), is between 3,990 and 9,576 megalitres
- based on the 2005 event, an environmental water release of approximately 35,000 megalitres and a peak discharge of 2,800 ML/d at Willandra Weir would be required to flood a core area of the swamp
- piggybacking environmental water onto unregulated flows is a good watering option.

Asset: Great Cumbung Swamp

The Great Cumbung Swamp (GCS) has been a terminal wetland for thousands of years and is listed in *A Directory of Important Wetlands in Australia*, published by the Australian Government. The swamp includes a variety of wetland areas and covers approximately 15,000 hectares. The GCS and its associated floodplain support one of the largest areas of common reed and stands of river red gum in NSW. The Cumbung is now well-inundated after receiving flows in 2010–11. However, prior to this latest inundation the vegetation of the Cumbung was in poor condition as a result of drought conditions experienced over the past 10 years.

The GCS includes a number of water management areas, such as the reed bed. The water management areas have yet to be determined as the Lachlan CMA has not made available the hydrodynamic modelling study by consultancy Parsons Brinkerhoff. Sub-units within GCS include Boocathan (lake and swamp), Bunumburt Lake, Narran Lake, Brittens Lake and Little Brittens Lake, Dead Tree Swamp, Clear Lake, Dry Lake, Hut Swamp and Sapling Swamp.

The GCS, under natural conditions, would have flooded in late winter to early spring and dried under drought conditions. A number of existing (unauthorised) levees, channels and regulating structures, some installed at the time of pastoral settlement, have changed inundation patterns in the GCS. Landholders have generally selectively flooded areas of the GCS to enhance grazing opportunities. There has been no prior systematic analysis of the capability of these structures, although this may have been done as part of the hydrodynamic modelling study.

Relevant water delivery information for the GCS includes:

- Travel time is 90 days from Wyangala Dam and nearly 70 days from Lake Brewster.
- CTF—because the Lachlan River terminates in the GCS all flows entering will result in some flooding. At flows of about 700 ML/d at Booligal Weir there is some flooding of the reed bed. Flows of between 1,500 and 3,000 ML/d at Booligal Weir will start to flood the broader wetland and this flooding will increase depending on the duration of these flows. In this regard the hydrodynamic model could provide further information (if so. the above information can be revised).
- the volume-to-fill is estimated to be 5,000 megalitres for the reed bed and 30,000–45,000 megalitres to achieve river red gum inundation.

Appendix 3: Probabilities of unregulated flows in the Lachlan River at Willandra and Booligal Weirs

Daily flows for various exceedance percentiles at Booligal and Willandra have also been determined. These are presented for each month for extreme-dry-to–extreme-wet scenarios. These results are based on an analysis of more than 100 years of modelled flows for current development and water-sharing plan rules. Annual flow totals were firstly ranked. Years corresponding to a particular climatic condition were then extracted and daily flows were then analysed to produce information on the percentage of time a flow threshold was exceeded together with the average duration (Avg d) of days above the flow threshold. This was undertaken for each month. For example, in Table 15 a January flow of 336 ML/d will be exceeded for 40 per cent of the time, with events exceeding 336 ML/d for an average duration of five days. January flow will be at least 309 ML/d (i.e. 100 per cent probability of being exceeded) with a maximum flow of about 588 ML/d (i.e. exceeded very rarely).

Further analysis of these events is likely to be required at several sites to determine potential threshold events for the possible use of held environmental water via piggybacking.

Table 15: Probabilities of unregulated flows being exceeded under extreme dry conditions—Willandra

	Jan		Feb		Mar		Apr		May		Jun		Jul		Aug		Sep		Oct		Nov		Dec	
%	Flow	Avg d	Flow	Avg d	Flow	Avg d	Flow	Avg d	Flow	Avg d	Flow	Avg d	Flow	Avg d	Flow	Avg d	Flow	Avg d	Flow	Avg d	Flow	Avg d	Flow	Avg d
100	309	31	301	28	295	31	46	30	75		0		30		31	31	238	30	305	31	301	30	299	31
90	323	31	317	26	321	31	112	30	80	31	74	30	62	31	210	31	284	30	312	31	317	26	321	20
80	330	19	322	12	483	21	462	30	351	31	75	30	234	31	281	28	288	30	316	19	322	13	324	12
70	333	8	326	8	491	10	518	12	436	14	424	18	283	12	290	12	295	30	318	22	323	13	328	11
60	334	7	328	6	494	7	525	8	439	8	434	7	286	10	290	12	296	30	322	11	326	11	329	8
50	335	6	329	6	498	7	529	7	440	7	435	5	286	8	302	16	303	28	326	10	329	8	330	7
40	336	5	330	4	499	6	531	6	441	4	436	3	288	6	303	11	308	14	329	5	333	12	332	9
30	336	4	332	4	500	5	532	4	443	4	437	3	289	6	303	5	309	11	332	4	340	6	344	8
20	347	4	333	3	502	5	532	3	445	3	439	3	302	5	303	4	316	8	334	3	341	4	346	4
10	355	2	335	2	527	3	532	2	499	4	443	1	305	4	303	4	323	6	336	2	343	3	349	3
0	588	1	404		543	1	611	1	633	1	466	1	310	1	332	1	457	1	344	1	352	1	396	1

Table 16: Probabilities of unregulated flows being exceeded under dry conditions—Willandra

	Jan		Feb		Mar		Apr		May		Jun		Jul		Aug		Sep		Oct		Nov		Dec	
%	Flow	Avg d	Flow	Avg d	Flow	Avg d	Flow	Avg d	Flow	Avg d	Flow	Avg d	Flow	Avg d	Flow	Avg d	Flow	Avg d	Flow	Avg d	Flow	Avg d	Flow	Avg d
100	519	31	293	28	298	31	360	30	410	31	279	31	252	31	91	31	78	30	334	31	345	30	308	31
90	697	31	339	28	454	31	518	23	435	23	398	30	302	24	303	28	318	30	417	31	518	29	566	31
80	729	21	578	28	492	11	527	12	441	12	434	11	305	15	307	23	366	26	502	19	586	32	621	25
70	746	20	698	13	503	10	530	8	445	12	438	9	308	15	343	18	456	16	617	14	625	23	687	24
60	814	20	725	8	519	10	532	7	448	9	441	12	322	16	394	14	505	16	708	10	745	17	781	26
50	863	7	746	8	551	11	533	7	456	8	445	7	352	25	416	11	606	10	764	8	791	13	825	15
40	907	5	772	8	612	12	542	7	466	8	448	7	373	10	458	11	666	8	842	5	840	11	857	8
30	953	4	897	10	728	6	556	5	483	7	450	4	399	10	525	6	702	5	883	4	907	8	897	5
20	1,020	4	1,165	4	814	5	567	4	522	5	454	4	445	7	549	5	769	4	974	4	961	6	928	4
10	1,196	3	1,274	2	1,020	6	623	3	584	3	504	16	507	5	615	4	914	3	1,194	3	1,056	5	985	3
0	1,417	1	1,723	1	1,472	1	820	1	676		593	1	1,915	1	4,501	1	4,829	1	5,096	1	4,996	1	1,367	1

Table 17: Probabilities of unregulated flows being exceeded under median conditions—Willandra

	Jan		Feb		Mar		Apr		May		Jun		Jul		Aug		Sep		Oct		Nov		Dec	
%	Flow	Avg d	Flow	Avg d	Flow	Avg d	Flow	Avg d	Flow	Avg d	Flow	Avg d	Flow	Avg d	Flow	Avg d	Flow	Avg d	Flow	Avg d	Flow	Avg d	Flow	Avg d
100	715	31	310	28	352	31	420	30	323	31	293	30	76	31	230	31	84	30	324	31	329	30	306	31
90	814	31	688	26	490	24	518	25	442	40	407	25	292	31	365	31	375	30	428	31	509	30	599	31
80	894	14	820	16	529	10	525	12	449	13	434	13	306	31	497	16	456	26	511	31	657	30	779	31
70	957	9	878	14	545	9	530	10	452	9	441	9	342	25	533	16	517	15	628	30	767	23	903	13
60	1,013	9	997	8	570	11	532	9	455	8	447	7	385	10	578	9	576	12	707	23	884	13	943	8
50	1,084	6	1,082	7	666	14	538	13	460	7	451	6	428	9	609	11	679	12	833	13	952	10	988	8
40	1,124	5	1,165	6	800	10	551	7	466	7	454	7	470	8	1,200	18	734	11	988	9	987	6	1,015	6
30	1,191	4	1,200	6	1,030	9	558	6	487	5	461	6	509	6	3,721	13	983	5	1,089	6	1,015	5	1,036	5
20	1,224	3	1,284	3	1,215	5	601	7	524	4	472	7	579	4	4,406	5	1,200	5	1,184	7	1,062	5	1,073	4
10	1,580	10	1,409	2	1,414	4	790	8	624	3	534	6	945	6	5,565	7	4,724	5	1,333	3	1,124	4	1,121	3
0	7,385	1	2,210	1	5,805	1	6,780	1	3,512	1	6,616	1	5,664	1	6,725	1	5,936	1	4,573	1	7,282	1	1,288	1

Table 18: Probabilities of unregulated flows being exceeded under wet conditions—Willandra

	Jan		Feb		Mar		Apr		May		Jun		Jul		Aug		Sep		Oct		Nov		Dec	
%	Flow	Avg d	Flow	Avg d	Flow	Avg d	Flow	Avg d	Flow	Avg d	Flow	Avg d	Flow	Avg d	Flow	Avg d	Flow	Avg d	Flow	Avg d	Flow	Avg d	Flow	Avg d
100	1,097	31	640	28	314	30	379	30	366	31	296	30	241	31	84	31	435	30	350	31	304	30	365	31
90	1,200	31	1,104	28	538	22	523	20	446	26	433	25	304	31	352	31	1043	25	642	31	724	30	847	25
80	1,220	6	1,200	20	615	15	527	12	451	18	445	15	318	28	537	35	1,713	16	764	18	819	22	914	18
70	1,242	4	1,229	9	776	14	532	14	462	14	448	9	342	21	1,213	29	3,284	18	1,005	20	923	14	1,001	12
60	1,265	3	1,259	5	982	10	545	9	476	12	451	12	409	23	2,632	14	5,185	15	1,419	17	995	12	1,055	9
50	1,293	3	1,293	4	1,123	10	553	7	488	9	456	9	505	16	4,402	12	5,797	14	3,972	16	1,072	8	1,088	7
40	1,337	2	1,316	3	1,209	7	581	6	496	8	466	16	1,200	23	5,809	14	6,222	10	6,055	11	1,224	9	1,140	7
30	1,370	2	1,349	3	1,257	3	599	5	524	8	487	14	4,010	12	6,613	8	6,615	11	6,530	7	2,459	10	1,215	5
20	1,403	2	1,403	3	1,315	2	638	5	631	9	554	16	5,469	10	7,934	7	8,339	11	7,299	7	5,427	7	1,328	9
10	1,562	3	1,550	5	1,367	2	727	4	3,456	18	2,916	9	6,375	9	9,065	7	10,900	8	8,564	4	6,406	5	3,925	9
0	6,172	1	6,802	1	1,916	1	8,687	1	12,004	1	5,982	1	15,160	1	14,140	1	14,883	1	11,760	1	9,839	1	16,619	1

Table 19: Probabilities of unregulated flows being exceeded under extreme wet conditions–Willandra

	Jan		Feb		Mar		Apr		May		Jun		Jul		Aug		Sep		Oct		Nov		Dec	
%	Flow	Avg d	Flow	Avg d	Flow	Avg d	Flow	Avg d	Flow	Avg d	Flow	Avg d	Flow	Avg d	Flow	Avg d	Flow	Avg d	Flow	Avg d	Flow	Avg d	Flow	Avg d
100	1,026	31	1,083	28	440	31	388	30	402	31	279	30	1,213	31	7,018	31	1,429	30	886	31	690	30	875	31
90	1,200	31	1,200	28	573	31	519	23	441	30	421	30	3,680	31	9,956	31	7,235	27	1,903	31	1,002	29	968	15
80	1,215	7	1,231	8	648	15	526	11	457	25	440	30	5,702	31	12,134	31	9,205	24	5,145	31	1,346	37	1,016	9
70	1,239	4	1,266	5	927	15	531	9	465	12	445	30	7,198	31	13,993	22	9,770	26	6,224	17	3,131	25	1,053	8
60	1,247	3	1,303	4	1,172	13	548	12	468	9	448	30	9,880	31	15,161	16	10,116	22	6,456	12	6,299	16	1,116	7
50	1,268	3	1,318	4	1,219	6	551	6	472	7	454	30	10,647	27	16,191	16	10,689	19	6,759	13	7,785	15	1,141	5
40	1,300	2	1,339	3	1,256	4	554	6	480	9	459	30	11,565	12	17,261	16	12,010	15	7,734	12	10,447	20	1,191	7
30	1,322	2	1,371	2	1,285	2	568	5	491	5	491	30	14,947	16	19,104	12	12,893	11	8,084	9	13,260	15	1,287	6
20	1,396	2	1,443	2	1,325	2	596	6	515	4	540	30	22,987	16	20,411	10	14,204	8	9,324	10	15,265	10	1,469	8
10	1,556	5	1,558	1	1,391	2	623	4	586	3	576	30	26,621	8	24,732	8	18,280	15	11,061	8	17,795	15	6,122	8
0	6,875	1	4,546	1	1,838	1	718	1	675	1	14,584	2	66,231	1	30,678	1	29,595	1	21,449	1	25,711	1	7,890	1

Table 20: Probabilities of unregulated flows being exceeded under extreme dry conditions - Booligal

	Jan		Feb		Mar		Apr		May		Jun		Jul		Aug		Sep		Oct		Nov		Dec	
%	Flow	Avg d	Flow	Avg d	Flow	Avg d	Flow	Avg d	Flow	Avg d	Flow	Avg d	Flow	Avg d	Flow	Avg d	Flow	Avg d	Flow	Avg d	Flow	Avg d	Flow	Avg d
100	0		0		0		0		0		0	30	0		0		77	30	0		0		0	
90	0		0		0	30	45	31	0	31	0	30	20	31	42	31	96	19	0	31	51	30	12	23
80	0	22	0	21	76	21	90	16	12	31	0	30	78	31	88	31	97	13	37	23	77	15	53	25
70	23	15	0	19	98	11	100	11	93	19	98	13	95	14	97	12	99	10	87	17	91	11	87	15
60	45	12	37	24	100	6	107	9	97	10	99	8	98	9	100	7	100	7	99	9	100	9	97	9
50	76	15	94	17	100	5	111	8	100	6	100	5	100	8	101	5	102	7	103	6	104	5	99	6
40	99	8	99	10	101	3	119	9	101	5	100	4	100	6	102	5	106	6	107	4	106	4	101	5
30	100	4	100	4	102	3	125	5	105	3	101	4	102	5	106	4	110	4	109	3	108	3	104	3
20	100	2	100	3	107	2	125	3	115	3	103	4	109	3	112	3	129	4	114	3	110	3	107	3
10	103	2	108	4	112	3	127	3	126	2	107	2	120	2	124	3	158	3	174	3	116	3	110	3
0	333	1	255	1	385	1	147	1	159	1	115	1	176	1	255	1	340	1	345	1	373	1	586	1

Table 21: Probabilities of unregulated flows being exceeded under dry conditions - Booligal

	Jan		Feb		Mar		Apr		May		Jun		Jul		Aug		Sep		Oct		Nov		Dec	
%	Flow	Avg d	Flow	Avg d	Flow	Avg d	Flow	Avg d	Flow	Avg d	Flow	Avg d	Flow	Avg d	Flow	Avg d	Flow	Avg d	Flow	Avg d	Flow	Avg d	Flow	Avg d
100	0		0		0		21	31	9	31	52	30	66	31	32	31	29	30	0		36	30	0	
90	0	20	0		2	31	100	15	87	23	97	17	97	18	90	24	92	18	0	31	73	21	71	31
80	20	28	0	18	71	31	106	11	96	10	99	15	100	11	99	10	98	11	55	21	88	12	92	19
70	70	20	0	16	93	8	112	8	99	8	100	10	101	8	104	10	102	8	93	8	95	7	99	10
60	94	9	25	15	99	5	116	9	102	6	100	8	104	6	109	7	107	6	101	5	103	6	104	10
50	100	7	83	11	103	4	122	6	105	4	100	7	108	5	116	6	110	5	105	4	110	5	107	5
40	104	5	98	5	108	3	124	5	107	3	101	6	110	4	124	5	116	5	114	4	120	5	109	5
30	110	4	107	4	113	3	126	5	110	4	105	9	116	4	153	5	127	4	130	3	160	4	116	5
20	120	3	124	3	119	3	135	5	118	2	108	5	140	3	197	4	179	3	179	3	213	3	152	5
10	174	2	206	3	141	3	150	3	131	2	109	3	173	3	247	3	259	3	282	3	308	2	281	5
0	428	1	695	1	900	1	599	1	375	1	512	1	856	1	1,057	1	1,137	1	732	1	925	1	757	1

Table 22: Probabilities of unregulated flows being exceeded under median conditions - Booligal

	Jan		Feb		Mar		Apr		May		Jun		Jul		Aug		Sep		Oct		Nov		Dec	
%	Flow	Avg d	Flow	Avg d	Flow	Avg d	Flow	Avg d	Flow	Avg d	Flow	Avg d	Flow	Avg d	Flow	Avg d	Flow	Avg d	Flow	Avg d	Flow	Avg d	Flow	Avg d
100	0		0		0		0		19	31	53	30	66		41	31	38	30	0		42	30	47	31
90	0		0		0		88	17	81	31	95	21	100	20	101	31	96	24	38	31	80	26	89	19
80	0	28	0		0		100	10	95	14	98	16	104	11	107	15	104	18	74	14	95	14	99	14
70	37	26	0	20	0	14	104	9	99	9	100	11	107	9	116	10	111	13	100	9	106	9	108	10
60	69	10	29	13	38	12	112	8	102	7	101	8	109	7	124	9	139	12	113	6	112	7	116	7
50	94	7	55	8	80	7	115	7	105	5	103	6	113	5	159	9	208	13	131	5	127	6	133	7
40	109	6	77	6	98	5	121	6	108	4	105	6	122	5	212	7	386	13	175	5	158	5	188	6
30	168	6	103	5	111	4	126	4	115	4	106	5	157	5	269	9	822	12	264	6	213	5	300	5
20	257	5	258	5	181	3	139	3	125	4	108	4	192	7	1,109	9	1,438	9	467	10	353	6	399	4
10	483	5	511	4	347	3	288	11	159	6	111	3	687	9	1,807	9	1,861	4	1,632	9	1,010	11	550	3
0	1,146	1	2,284	1	1,860	1	1,647	1	2,577	1	287	1	2,284	1	2,731	1	2,908	1	2,788	1	2,568	1	2,913	1

Table 23: Probabilities of unregulated flows being exceeded under wet conditions – Booligal

	Jan		Feb		Mar		Apr		May		Jun		Jul		Aug		Sep		Oct		Nov		Dec	
%	Flow	Avg d	Flow	Avg d	Flow	Avg d	Flow	Avg d	Flow	Avg d	Flow	Avg d	Flow	Avg d	Flow	Avg d	Flow	Avg d	Flow	Avg d	Flow	Avg d	Flow	Avg d
100	0		0		0		41	30	35	31	86	30	82		35	31	58	30	0		42	30	32	31
90	27	17	0		0		77	19	85	31	98	21	99	23	100	31	198	30	105	28	124	20	78	23
80	45	10	15	21	0		99	10	98	14	100	11	104	17	118	28	622	30	184	21	175	16	108	16
70	58	6	46	13	15	93	109	9	102	9	101	11	109	10	203	22	1,186	26	758	34	313	19	130	16
60	80	6	78	7	39	20	111	6	106	7	104	11	114	10	786	36	1,559	18	1,803	34	517	20	187	12
50	97	7	117	7	73	6	118	7	112	6	107	9	121	10	1,286	27	1,867	14	2,319	24	1,133	18	366	9
40	116	5	168	6	106	4	124	6	119	5	112	15	147	10	2,091	29	2,134	12	2,715	11	1,643	15	512	10
30	151	5	287	5	139	4	139	5	138	7	126	21	201	17	2,510	18	2,386	9	2,894	13	2,080	12	991	13
20	328	6	440	5	263	3	185	5	708	35	1,637	14	1,642	19	2,795	12	2,872	16	3,313	12	2,647	17	1,737	11
10	949	15	888	8	475	2	460	3	3,391	18	2,049	6	2,229	11	3,396	13	3,725	11	3,511	5	3,413	8	2,459	17
0	3,864	1	2,483	1	2,341	1	3,068	1	5,595	1	3,234	1	2,852	15	4,141	1	4,255	1	4,158	1	3,705	1	3,420	1

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Table 24: Probabilities of unregulated flows being exceeded under extreme wet conditions - Booligal

	Jan		Feb		Mar		Apr		May		Jun		Jul		Aug		Sep		Oct		Nov		Dec	
%	Flow	Avg d	Flow	Avg d	Flow	Avg d	Flow	Avg d	Flow	Avg d	Flow	Avg d	Flow	Avg d	Flow	Avg d	Flow	Avg d	Flow	Avg d	Flow	Avg d	Flow	Avg d
100	0		0		0		48	30	37	31	59	30	95	31	93	31	884	30	62	31	741	30	83	31
90	47	20	2	18	0		87	16	94	24	94	30	114	29	120	31	2,353	30	459	31	1,850	30	141	31
80	73	11	30	19	0		100	11	100	11	97	16	1,270	93	2,273	31	3,618	30	2,138	31	2,562	27	387	31
70	96	8	71	11	11	106	108	9	103	11	100	16	2,791	56	3,234	31	3,954	18	2,788	31	2,801	29	632	21
60	109	7	94	7	42	26	115	6	106	7	103	22	3,363	26	3,918	24	4,124	30	3,327	15	3,081	40	923	23
50	127	6	112	6	70	13	122	6	109	6	106	18	3,601	28	4,009	13	4,357	12	3,581	15	3,290	35	1,503	19
40	178	7	134	5	90	5	125	5	113	5	108	10	3,834	9	4,152	22	4,538	15	3,750	12	3,501	21	2,778	20
30	256	4	177	5	116	4	131	5	121	5	112	18	3,947	10	4,474	23	4,723	15	3,952	9	3,789	21	3,400	15
20	498	5	426	4	148	4	518	30	694	31	195	47	4,200	8	5,515	16	4,888	8	4,253	16	4,083	16	4,092	10
10	826	8	1,312	15	590	5	3,054	15	3,286	5	3,914	4	6,824	16	6,113	5	5,203	8	4,826	16	4,470	10	4,453	8
0	3,240	1	2,543	1	1,591	1	4,136	1	4,178	1	4,131	1	1,0811	1	6,993	1	5,535	1	5,773	1	5,389	3	5,549	

Appendix 4: Water order application form

Water Order Application Form

In accordance with the Water Management Act 2000 and Water Act 1912

Part 1 - Water order Type

New Water Order ☐
Amend existing order ☐
Cancel existing order ☐

Meter Reading Only ☐
Date original order submitted __ __ / __ __ / __ __ __ __

Part 2 - Water Access Licence Details

Licence Holder Name:

Licence Number: eg. 50AL000001 or 60AL000001 or 70AL000001

Part 3 - Combined Approval or Works Approval Details

CA or WA Number : eg. 50CA000001 or 60WA000001 or 70WA000001

Extraction Site: eg. ESID or meter number or pump description.

Part 4 - Extraction Details

Bulk Order — Orders that will **not** vary on a daily basis

or

Daily Order — For orders that vary volume on a daily basis.

Start Date	__ __ / __ __ / __ __ __ __
Number of Days Pumping	
Volume per day	ML

Start date **MUST** comply with lag day requirements and cannot exceed a period of one month.

Date	ML/Day

Part 5 - Current Meter Reading(s)

Date	*Pump Description*	*Reading*

Part 6 - Authorisation declaration (Mandatory)

☐ I am/we are authorised to make this application on behalf of the holder(s) of this licence.

Name(s):

Signature:
Application Date: __ __ / __ __ / __ __ __ __

Phone:
Fax:

How to submit this form *Enquiries please call 1300662077*

Fax to: 1300871447 Email:
North.Orders@statewater.com.au – Gwydir, Namoi, Borders Rivers
Central.Orders@statewater.com.au – Macquarie, Lachlan, Hunter, Coastal
South.Orders@statewater.com.au – Murray\Lower Darling, Murrumbidgee

Please keep a copy of completed form for your record

Taking of water without submitting a valid water order is an offence.

Appendix 5: SEWPaC risk matrix

	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 water loss 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.

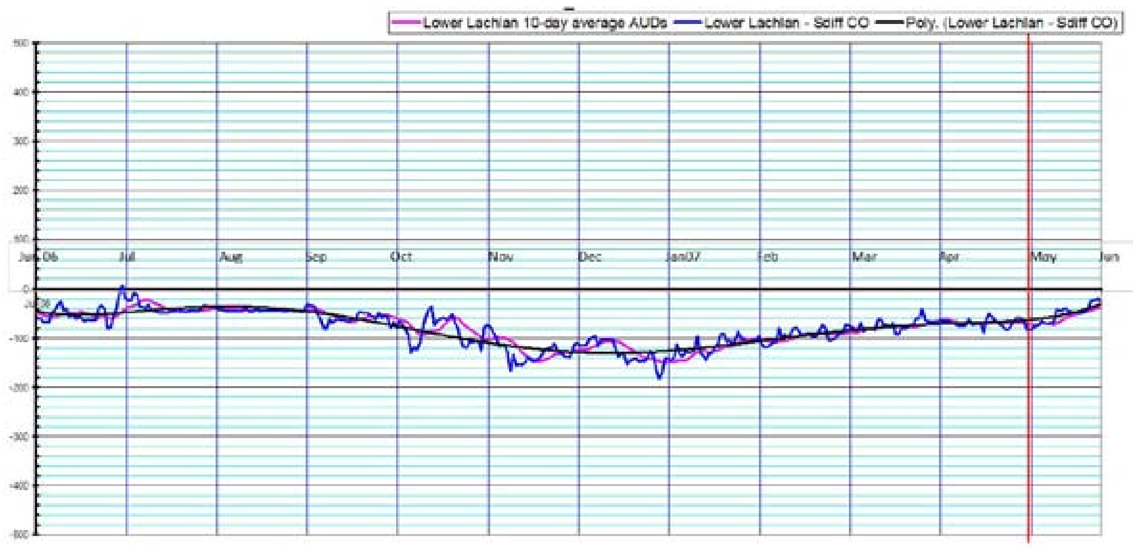
LIKELIHOOD	CONSEQUENCE Insignificant No environmental damage.	Minor Minor instances of environmental damage that could be reversed.	Moderate Isolated but significant instances of environmental damage that might be reversed with intensive efforts.	Major Severe loss of environmental amenity and danger of continuing environmental damage.	Critical Major widespread loss of environmental amenity & progressive irrecoverable environmental damage.
Almost certain Is expected to occur in most circumstances.	Low	Medium	High	Severe	Severe
Likely Will probably occur in most circumstances.	Low	Medium	Medium	High	Severe
Possible Could occur at some time.	Low	Low	Medium	High	Severe
Unlikely Not expected to occur.	Low	Low	Low	Medium	High
Rare May occur in exceptional circumstances only.	Low	Low	Low	Medium	High

Appendix 6: Lachlan seasonal base flow requirements

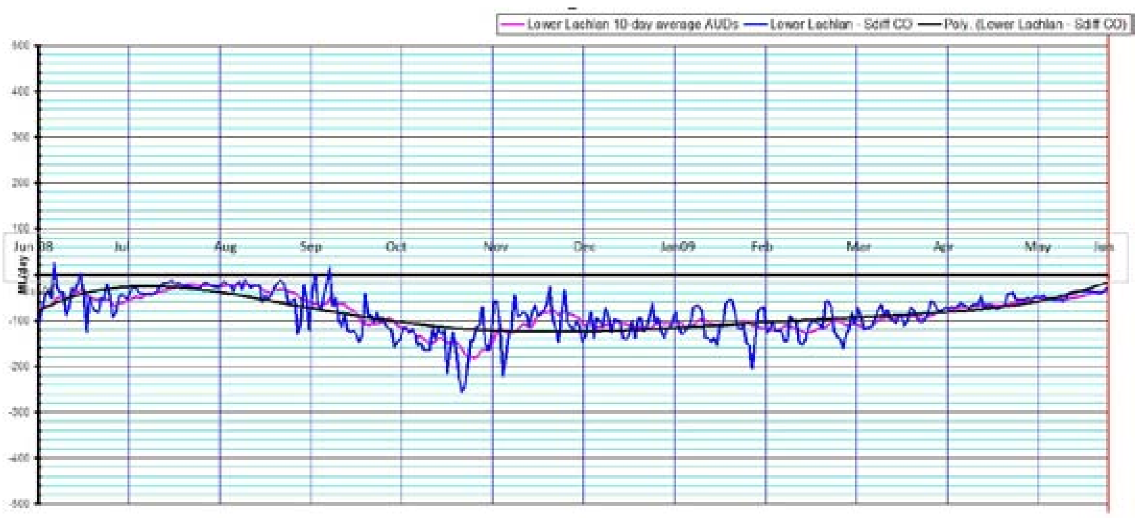
Source: State Water

Upper Lachlan Seasonal Base Flow, June 2006 to June 2007 (to Lake Cargelligo)

Upper Lachlan Seasonal Base Flow, June 2008 to June 2009 (to Lake Cargelligo)



Lower Lachlan Seasonal Base Flow, June 2006 to June 2007 (Below Lake Cargelligo)



Lower Lachlan Seasonal Base Flow, June 2008 to June 2009 (Below Lake Cargelligo)

Australian Government

Commonwealth Environmental Water

ENVIRONMENTAL WATER DELIVERY

Loddon River

AUGUST 2011 V1.0

Image Credits

Loddon River with birds and dead tree
© MDBA Photographer Arthur Mostead

Loddon RIver
© MDBA Photographer Arthur Mostead

Peter Cottingham & Associates and SKM (2011). *Environmental Water Delivery: Loddon River.* Prepared for Commonwealth Environmental Water, Department of Sustainability, Environment, Water, Population and Communities, Canberra.

ISBN: 978-1-921733-26

SEWPaC acknowledges the following individuals and organisations that have been consulted in the preparation of this document:

Michael Jensz (Department of Sustainability and Environment, Victoria)
Mark Bailey (Goulburn-Murray Water)
Andrew Shields (Goulburn-Murray Water)
Philip Slessar (North Central Catchment Management Authority)
Darren White (North Central Catchment Management Authority)
Geoff Earl (Goulburn Broken Catchment Management Authority)
Garry Smith (DG Consulting)
Ben Gawne (Murray-Darling Freshwater Research Centre)
Daren Barma (Barma Water Resources)
Murray-Darling Basin Authority

Published by the Commonwealth Environmental Water Holder for the Australian Government.

ENVIRONMENTAL WATER DELIVERY

Loddon River

AUGUST 2011 V1.0

Environmental Water Delivery: Loddon River

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 Loddon River and four Boort district wetlands.

Both the Loddon River and Boort district wetlands support flora and fauna of international, national, regional and local conservation significance, including two waterbirds listed under international agreements. Potential water use options for the Loddon River include the provision of a winter-spring high bankfull flow along Reach 4 to avoid the build-up of organic matter, maintain riparian vegetation condition and support natural geomorphologic processes; as well as provision of a spring fresh to create habitat variability for macrophytes and macroinvertebrates. Options for the Boort wetlands include the provision of water to complete the desired filling and drying pattern to maintain/rehabilitate the health of aquatic plant communities and fringing vegetation.

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

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

Commonwealth Environmental Water
Department of Sustainability, Environment, Water, Population and Communities
GPO Box 787, Canberra ACT 2601
Tel: +61 2 6275 9245

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Acronyms

ACRONYM	MEANING
BE	Bulk Entitlement
CAMBA	China-Australia Migratory Bird Agreement
CEWH	Commonwealth Environmental Water Holder
COAG	Council of Australian Governments
DO	Dissolved oxygen
DPI	Victorian Department of Primary Industries
DSE	Victorian Department of Sustainability and Environment
EC	Electrical conductivity
EPA	Victorian Environment Protection Authority
EVC	Ecological vegetation classes
eWater CRC	eWater Cooperative Research Centre
GBCL	Goulburn-Broken-Campaspe-Loddon
GB CMA	Goulburn Broken Catchment Management Authority
G-MW	Goulburn-Murray Water
IVTs	Inter-valley transfers
JAMBA	Japan-Australia Migratory Bird Agreement
MDBA	Murray-Darling Basin Authority
LREFSP	Loddon River Environmental Flows Scientific Panel
NC CMA	North Central Catchment Management Authority
NERWMP	North East Regional Water Monitoring Partnership
NCRHS	North Central River Health Strategy
NRSWS	The Northern Region Sustainable Water Strategy
NVIRP	Northern Victoria Irrigation Renewal Project
ROKAMBA	Republic of Korea – Australia Migratory Bird Agreement
SEWPaC	Australian Government Department of Sustainability, Environment, Water, Population and Communities
SKM	Sinclair Knight Merz
TLM	The Living Murray
VEFMAP	The Victorian Environmental Flows Monitoring and Assessment Program
VEWH	Victorian Environmental Water Holder
VWQMN	Victorian Water Quality Monitoring Network

PART 1:
Management Aims

1. Overview

1.1 Scope and purpose of this document

Information provided 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 systems' 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.

This document focuses on assets in the Loddon River and Boort wetlands system in northern Victoria. It includes options for the use of water held in Loddon storages, as well as options that might be pursued with access to environmental water held in the Goulburn system.

As part of this project, assets and potential watering options have been 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 options have been developed for each asset to meet watering objectives under a range of volume scenarios. Use of environmental water will aim to maximise environmental outcomes at multiple assets, where possible. Water use options will provide an "event ready" basis for the use of environmental water. Options are expected to be integrated into a five-year water delivery program.
3. Processes and mechanisms that are required to operationalise the environmental water use strategies are documented and include such things as:
   - delivery arrangements and operating procedures
   - water delivery accounting methods that are either currently in operation at each asset 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.

1.2 Catchment and river system overview

The Loddon River catchment covers approximately 1.5 million hectares or about 6.8 per cent of the area of Victoria. The river rises on the northern slopes of the Great Dividing Range, south of Daylesford, before flowing 430 kilometres northward to join the Murray River downstream of the Gunbower and Koondrook-Perricoota Forests (NC CMA 2010).

The Loddon River resides within a number of local government areas. These include the Loddon Shire, City of Greater Bendigo, Hepburn Shire, Central Goldfields Shire, Mt Alexander Shire, Gannawarra Shire and Campaspe Shire.

Land tenure along the Loddon River is a mixture of freehold, conservation reserve and State forest. Intensive horticulture occurs in the upper catchment, and mixed farming and cereal growing dominates the mid and lower catchments. Land use along the river is predominantly:

- Grazing of natural vegetation.
- Dryland agriculture and plantations (grazing modified pastures, cropping).
- Irrigated agriculture and plantations (irrigated modified pastures, irrigated perennial horticulture).
- Intensive uses (residential, services).
- Conservation and natural environments (nature conservation, managed resource protection).
- Remnant wetlands / marshes.

Three main streams of the upper catchment are the Loddon River, Tullaroop Creek and Bet Bet Creek, all meeting at Laanecoorie Reservoir. The Loddon River then flows towards the Murray River (Figure 1). In addition to numerous small water storages, the three main storages in the upper catchment are: Cairn Curran Reservoir (147,000 ML capacity), Tullaroop Reservoir (73,000 ML capacity) and Laanecoorie Reservoir (8,000 ML capacity).

Environmental flow proposals have been developed for the four main reaches (Figure 1, Section 1.3) of the Loddon River downstream of the major flow regulating structures (LREFSP 2002, NC CMA 2010). Drought and low water availability led to a Qualification of Rights in 2007 and the subsequent management of river flows to ensure the survival of key ecosystem assets (Cottingham et al. 2010). It is only with increased rainfall runoff and water storage in 2010 that the reinstatement of the environmental flow regime can be reconsidered.

At high flows the Loddon River breaks, at several locations, into the Wandella Creek to the west and the Tragowel Plains to the east. The Waranga Western Channel crosses the Loddon River catchment south of Boort and at the Loddon Weir. It carries water from the Goulburn system that can be released to the lower reaches of the Loddon River. The Macorna Channel crosses underneath the Loddon River upstream of Kerang to supply Murray River water to irrigators in the Torrumbarry system. This report does not explicitly consider the Loddon River from Kerang Weir to the Murray River, as managed flows in this Reach are predominantly supplied from diversions from the Murray River at Torrumbarry Weir.

The Boort district wetlands include (but are not limited to) Lake Boort, Lake Meran, Little Lake Meran, Lake Yando, and Lake Leaghur. They are a series of wetlands located to the west of the Loddon River and north of Loddon Weir (Figure 2), and are considered to be regionally important. Shallow freshwater marshes, such as Lake Yando, Lake Leaghur and Lake Boort support diverse vegetation such as reeds, river red gum, water couch, water milfoils and water ribbons (*Triglochin spp.*). These provide habitat for a variety of biota such as waterbirds, waterfowl and frogs.

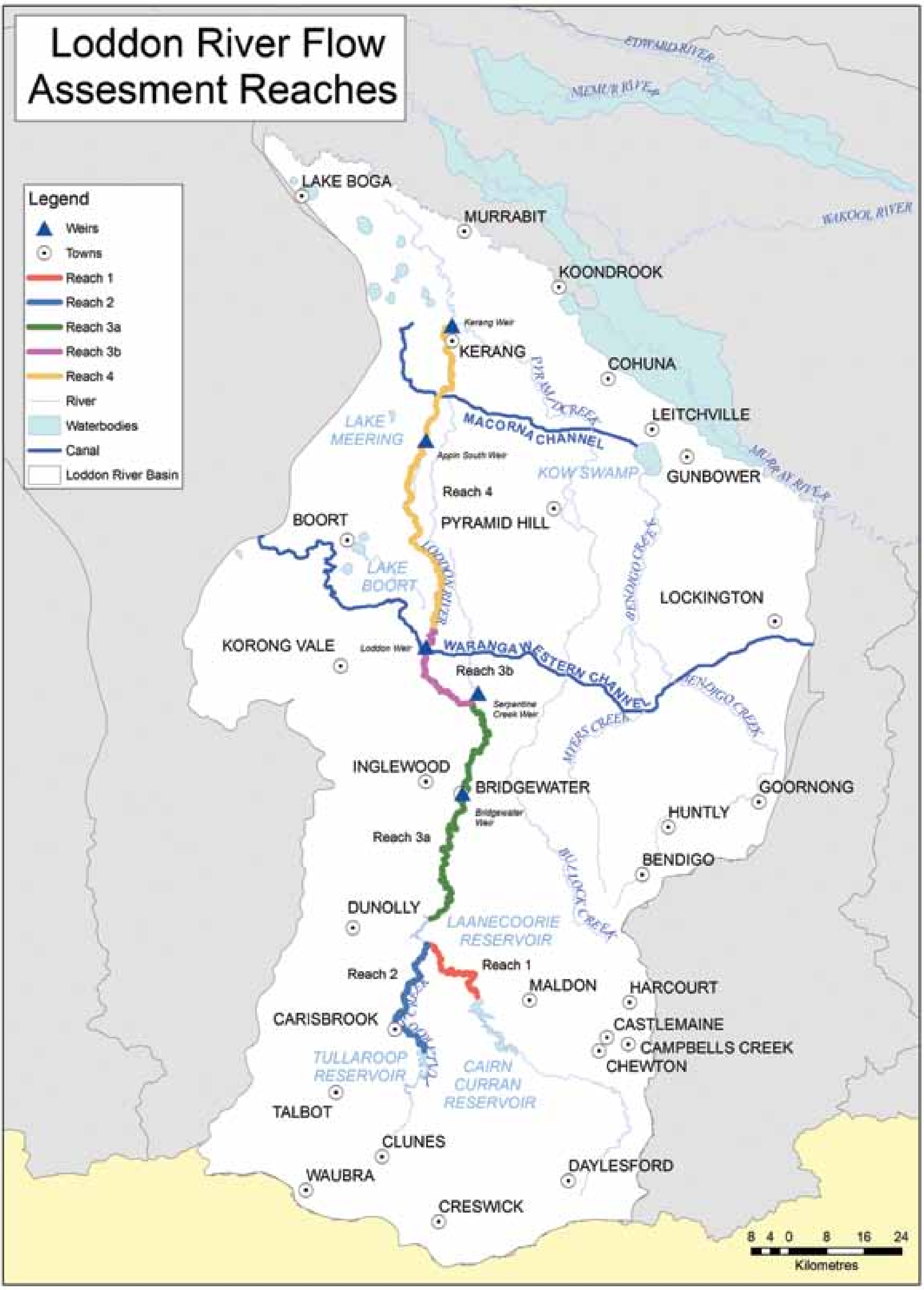

Figure 1: Loddon River flow assessment reaches (SEWPaC 2011).

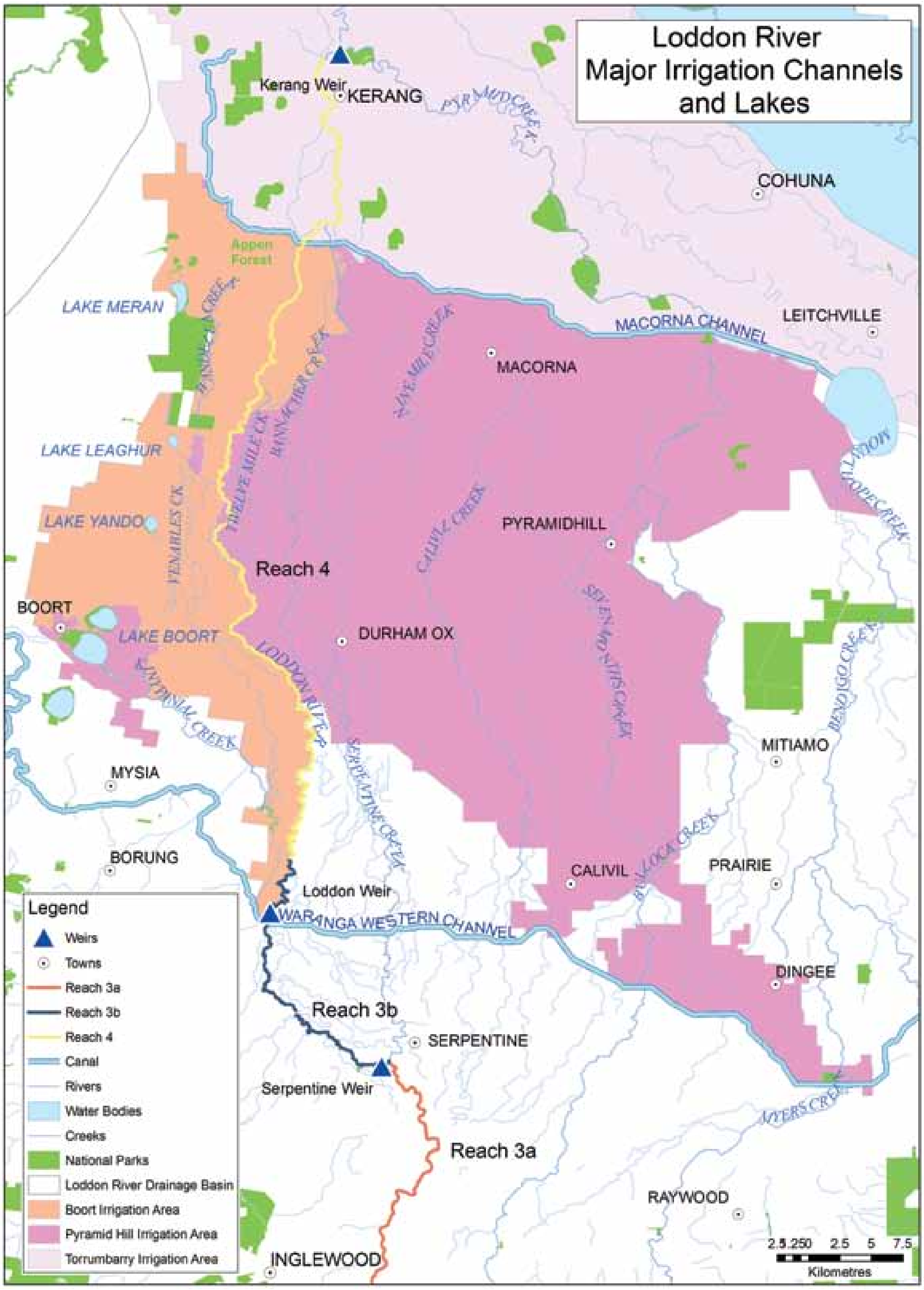

Figure 2: Loddon River major irrigation channels and lakes (SEWPaC 2011).

1.3 Overview of river operating environment

Environmental water is managed by the North Central Catchment Management Authority (NC CMA), in cooperation with the Victorian Environmental Water Holder (VEWH), Victorian Department of Sustainability and Environment (DSE) and Goulburn-Murray Water (G-MW), who manages river operations. Under the Bulk Entitlement (BE), the Loddon River is managed as four reaches:

Reach 1: Loddon River – Cairn Curran Reservoir to Laanecoorie Reservoir.
Reach 2: Tullaroop Creek – Tullaroop Reservoir to Laanecoorie Reservoir.
Reach 3a: Loddon River – Laanecoorie Reservoir to Serpentine Weir.
Reach 3b: Loddon River – Serpentine Weir to Loddon Weir.
Reach 4: Loddon River – Loddon Weir to Kerang Weir.

The river is generally operated to meet BE conditions at the top of Reach 4. Reach 5 (downstream of Kerang Weir to the Murray River) is operationally managed through the Torrumbarry Irrigation Area and forms part of the Victorian Murray BE. It is not specifically considered as part of the Loddon BE process and is not included in this document.

The Loddon River is highly regulated down to Loddon Weir to supply irrigation, stock and domestic and urban water demands. This has a major influence on the river's natural flow regime, including altered seasonal patterns of baseflow, reduced baseflow magnitude and reduced frequency of bankfull and flood flows (LREFSP 2002). Cairn Curran and Tullaroop Reservoirs are the main storages that collect water from the upper parts of the catchment. Laanecoorie Reservoir is used as a re-regulating storage for releases from Cairn Curran and Tullaroop Reservoirs. Water is drawn off Serpentine Weir to supply irrigators along Serpentine Creek. Flow into the Loddon River mixes with supply from the Waranga Western Channel at Loddon Weir pool. Loddon Weir to Kerang Weir is unregulated. The Macorna Channel, which is supplied from Torrumbarry Weir, crosses the Loddon River without interaction, apart from minor outfalls associated with channel operation. The lower Loddon River mixes with Pyramid Creek at Kerang Weir. Pyramid Creek carries irrigation supplies diverted from the Murray River at Torrumbarry Weir.

During high flow periods, there are numerous breakaway flows. Flood breakouts occur to the east (to the Tragowel Plains) and west (Wandella, Venables and Kinypanial Creeks and other tributaries) of the Loddon River. Water loss between Loddon Weir and Kerang Weir is poorly understood and high-flow data is uncertain.

Water reaches the Boort wetlands complex via local waterways and/or the local irrigation system. Prior to regulation, the wetlands in the complex would have filled in winter-spring. Regional development and water regulation caused isolation of some wetlands. Others were maintained as permanent or semi-permanent water bodies. The wetlands are now managed for their environmental values and a more natural cycle of filling (winter-spring) and drying has been reinstated.

2. Ecological values, processes and objectives

2.1 Summary of ecosystem values

The Loddon River and Boort district wetlands support flora and fauna of international, national, regional and local conservation significance (see NC CMA 2010a, b, c, Appendix 5). This includes waterbirds listed under international agreements (including JAMBA, CAMBA, ROKAMBA, and Bonn), threatened native fauna (including native fish) and flora.

The Loddon River provides breeding habitat for important fish species, such as the Murray cod and golden perch. Features such as pools (including weir pools) serve as important refugia for the survival of organisms that can recolonise reaches following periods of drought. After a period of cease-to-flow, protecting and then connecting in-channel habitat is important for the recovery of the river. The riparian zone of the Loddon River also supports important vegetation such as river red gums, chenopod grassland, lignum swamp and box-ironbark forest. The Loddon River is, therefore, a high priority for environmental water in the *North Central Regional River Health Strategy* and in annual watering plans written by the North Central CMA (NC CMA 2010).

Collectively, the Boort wetlands provide important breeding, feeding and refuge habitat for waterbirds (Parks Victoria 2003, NC CMA 2010b, c, d). At the landscape scale, the wetlands provide a great diversity of habitat types and drought refuges in a heavily modified landscape. The wetlands are visited by waterbird species (including those listed under JAMBA, CAMBA, ROKAMBA) such as Caspian tern, whiskered tern, great egret, Australasian shoveller, freckled duck, hardhead and blue-billed duck. The wetlands also support a variety of vegetation assemblages, including ecological vegetation classes (EVC) such as river red gum swamp, black box woodland, tall marsh and lignum swamp.

Table 1: General ecological objectives for targeted water use.

Water management area	Broad scale system objective	Ecological Objectives
Loddon River below the Loddon storages (Tullaroop, Cairn Curran and Laanecoorie) to Kerang Weir.	Deliver winter-spring flows that will provide a flow regime and conditions suitable to support habitat, flora and fauna. Sustain them beyond spring with an appropriate summer-autumn flow regime. Provide ecological connections to nearby floodplain ecosystems (e.g. Boort wetlands) as well as with the Murray River.	Deliver winter-spring bankfull and baseflow to avoid the build-up of organic matter, maintain riparian vegetation health and support natural geomorphologic processes. Deliver spring freshes and baseflow to provide habitat, as well as movement and breeding cues for fauna such as native fish. Deliver summer-autumn baseflow and freshes to provide habitat and suitable water quality in the river channel, as well as provide drought refuges for vulnerable biota. Deliver a flow regime that over time will support the biodiversity and asset objectives outlined in SKM (2010) and LREFSP (2002).
Boort wetland complex including (but not limited to) Lake Boort and Little Lake Boort, Lake Leaghur, Lake Meran and Lake Yando.	Maintain a more natural pattern of filling and drying at individual wetlands and across the wetland complex.	Deliver water to complete the desired filling and drying patterns at individual wetlands (NC CMA 2010b, c, d). This will maintain/rehabilitate aquatic plant communities and the health of fringing vegetation. It will also provide habitat and breeding opportunities for aquatic fauna and waterbirds.

More detailed watering objectives are presented in section 3.

3. Watering objectives

3.1 Broad-scale ecosystem objectives

3.1.1 Murray-Darling Basin

Work undertaken by the Murray-Darling Basin Authority (MDBA 2010) has produced a number of broad ecosystem objectives, the following of which are relevant when considering options for the use of environmental water:

- Maintain and improve the ecological health of the Basin, and in doing so optimise the social, cultural, and economic well-being of Basin communities.
- Improve the resilience of key environmental assets, water-dependent ecosystems and biodiversity in the face of threats and risks that may arise in a changing environment.
- Maintain appropriate water quality, including salinity levels, for environmental, social, cultural and economic activity in the Basin.

These and ecological objectives developed for the Loddon River system (see Table 1) will be important considerations when allocating environmental water in the Loddon system.

3.1.2 Loddon River

Flow-related ecosystem objectives for the Loddon River below Cairn Curran Reservoir (LREFSP 2002, Table 2) were outlined in the development of environmental flow proposals for Reaches 1–4. They were subsequently included in the Loddon River (Environmental Reserve) Bulk Entitlement (BE) Order 2005 (see Section 8.1.2). Flow proposals for Reach 4 and 5 were revisited (SKM 2010) in light of changed conditions (e.g. much of Reach 4 had been dry in recent years) and availability of better hydrological information, which had limited the recommendation of LREFSP (2002). The more recent objectives for Reach 4 are given in Table 3. The objectives for Reaches 1–3b remain unchanged – the fundamental management approach is to maintain, as a minimum, passing flows according to the Loddon BE.

Table 2: Summary of suggested environmental flow objectives for the Loddon River (LREFSP 2002).

Biodiversity Objective	No.	Process	Draft Flow Objective	
			Flow Component	Timing
Restore or maintain River blackfish population	1a	Habitat availability	Low (depth >0.4m)	All year
	1b	Breeding/Recruitment	Low	Spring
	1c	Movement	Low	All year
Restore or maintain native fish community (Marray cod, Golden perch and Silver perch)	2a	Available habitat and movement for all fish	All (depth >0.5m)	All year
	2b	Breeding cues for Murray cod	Freshes	Winter/Spring
	2c	Breeding cues for Golden perch	Freshes	Winter/Spring
	2d	Breeding cues for Silver perch	Freshes	Winter/Spring
Reinstate or maintain a mosaic of aquatic macrophytes	4a	Colonisation	Low	Spring
	4b	Disturbance	Low/Cease-to-flow	Summer
	4c	Habitat maintenance	Freshes	All year
Improve in-stream macrophyte habitat	4d	Colonisation/growth	Low	Spring/Summer
Improve submerged macrophyte habitat	4e	Colonisation/growth	Low (depth <0.3m)	Spring/Summer
Reinstate a mosaic of bank vegetation	5a	Colonisation/growth	All	Spring/Summer
	5b	Disturbance	Low/Cease-to-flow	Summer
	5c	Wetting	Freshes	Winter/Spring
Reverse terrestrialisation of bank/bench grasses	6	Disturbance	Freshes/High	Winter/Spring
Maintain red gum regeneration	7a	Wetting	Overbank	Spring
Restore or maintain floodplain/ wetland processes	7b	Inundation	Overbank	Spring
Clean bed surface	8a	Disturbance	Freshes	Any time
Restore or maintain pools	8b	Scour	High	Any time
Restore or maintain runs	8c	Disturbance	Freshes/High	Any time
Re-shape in-channel forms to maintain physical habitat diversity and complexity	8d	Scour/deposition	Freshes/High	Any time
Scour silt on bed	8e	Scour	High/Overbank	Any time
Restore or maintain snag	9	Submergence	Low	Any time
Entrain organic litter – carbon cycling	10	Disturbance	High	Winter

Table 3: Summary of proposed environmental watering objectives and anticipated responses for Reach 4 (from SKM 2010).

Asset	Objective	Function	Flow component	Timing	Expected response
Geomorphology	Maintain channel form and processes along the main channel of the Loddon and its system of distributaries, such as Twelve Mile Creek, Kinypanial Creek, Bannagher Creek and Venables Creek.	Channel maintenance.	Freshes / high flows	Summer and winter	• Maintain channel complexity, pools and benches.
		Channel forming processes.	Bankfull	Winter, spring or early summer	• Maintain channel form and floodplain features as a bankfull flow may also engage distributary channels.
		Creation of new flow paths across floodplain.	Bankfull and overbank	Winter-spring	• Engage floodplain and distributary channels. • Formation of new distributary channels.
Vegetation	Maintain/rehabilitate in-stream aquatic vegetation and ecological processes in main channel. Control existing invasion of main channel with non-aquatic species. Maintain or rehabilitate flood-dependent riparian and floodplain ecological vegetation classes (EVC). Rehabilitate river-floodplain ecological interactions and ecological processes on floodplain.	Establish aquatic environment for in-stream aquatic vegetation (e.g. pondweeds, water ribbons etc).	Low flow	Summer and winter	• Re-establishment of aquatic vegetation in in-stream channel. • Progressive control of invading river red gum in in-stream environments. • Possible (but uncertain) control of invading common reed in in-stream environments. • Improvement in condition of adult riparian and floodplain vegetation, especially river red gum. • Improvement in recruitment of juvenile plants into riparian and floodplain vegetation. • Increased floristic and structural complexity of floodplain vegetation (particularly understorey). • Engagement of floodplain with river: translocation of organic detritus and fauna/flora across floodplain-river ecotone.
		Drown-out invading terrestrial plant species (e.g. common reed, river red gum).	Low flow	Winter	
		Maintain adults of plant species in relevant riparian and floodplain EVCs (e.g. river red gum, black box).	Bankfull and overbank	Winter, spring or early summer	
		Facilitate recruitment of juveniles into relevant riparian and floodplain EVCs.	Bankfull and overbank	Winter, spring or early summer	
		Engage floodplain with river to entrain litter and allow movement of fauna across river floodplain.	Overbank	Winter-spring	

Asset	Objective	Function	Flow component	Timing	Expected response
Water quality	Improve water quality. Reduce incidence and severity of blackwater events. Limit impacts associated with acid sulfate soils (ASS).	Connecting flow sufficient to maintain water quality, prevent algal blooms and acidity from acid sulfate soils.	Low	Summer	• Annual bankfull flows are required to entrain organic matter that has accumulated in the channel margins to decrease the risk of blackwater events during summer. Continuously flowing water and occasional freshes in summer will prevent algal blooms and ensure that adverse water quality conditions (e.g. low DO, high temperatures, acidity from acid sulfate soils) do not develop. Note: summer fresh should not be delivered in the absence of winter/spring bankfull flows. • Cease to flow periods may be used to control the severity of acid sulfate soils by periodically allowing the sediments to oxygenate.
		Turn over water in pools for re-oxygenation of water column and sediments. Entrain terrestrial organic matter that has accumulated on bars and benches.	Fresh	Summer	
		Transport organic matter that has accumulated in the channel.	Bankfull	Winter	
		Control acid sulfate soils.	Cease to flow	Summer	
Fish	Maintain pools or depressions in the bottom of channels that fish may opportunistically use when wet.	Scour pools to provide depth and habitat variety in the bottom of the channel.	High to bankfull flows	Summer and winter	• Provide pools and debris in channels that will improve the quality of fish habitats. • Expect fish to use this reach opportunistically when wet. Small-bodied fish may complete their life cycle in wet periods. Large-bodied fish are more likely to use this habitat on a temporary basis.
		Facilitate movement of fish.	High flows	Spring and summer	
		Maintain aquatic habitat. This is probably a lower priority for Reach 4 because it will dry out periodically.	Low flows	Winter and spring	
Macroinvertebrates	Maintain habitat quality.	Inundate exposed roots, emergent vegetation and woody debris.	Low flows	All year round	• Increase diversity, abundance and distribution of macroinvertebrates throughout the reach.
		Flush sediment from hard substrate elements.	Fresh	Summer	

Environmental flow proposals for the Loddon River (particularly Reach 4) include provisions for bankfull flows, rather than large overbank flows. Bankfull flows engage with important geomorphic features such as anabranches and flood-runners. Overbank flows occur naturally and are desirable but have not been the focus of environmental flow recommendations due to the risk associated with flooding private land.

Options for using environmental water to meet flow objectives for the Loddon River will vary depending on ecosystem needs at any particular time, as well as the availability of environmental water held in the Goulburn and Campaspe systems. In isolation, the volume of Commonwealth environmental water held in Loddon storages is small and would only make a small contribution in meeting the flow objectives along the Loddon River. It could, however be used to water wetland assets in the Boort wetland complex. If Commonwealth environmental water is available from the Goulburn or Campaspe systems, it could be used to achieve desired environmental outcomes in the Loddon River (Reach 4) and the Boort wetlands.

3.1.3 Boort wetlands

In summary, objectives for the Boort wetlands are to:

- Maintain emergent aquatic plant communities.
- Maintain health of the fringing vegetation, including river red gum, blackbox, tangled lignum and cane grass.
- Restore open water/submerged aquatic macrophyte habitat in the deeper sections of the wetlands.
- Restore habitat and breeding opportunities for waterbirds, fish, frogs and invertebrates (NC CMA 2010b, c, d).

3.2 Asset watering objectives

3.2.1 Loddon River

Minimum flows and summer freshes are delivered to Reaches 1–3b under Bulk Entitlement arrangements. Flows are complemented by G-MW's river operations in most years, and by natural flows in average to wet scenarios, particularly if storages spill. Environmental water being sourced from Tullaroop and/or Cairn Curran reservoirs for delivery to Reach 4 is also likely to have environmental benefits in Reaches 1 to 3b as it passes through the system (NC CMA 2011). Environmental water in the Loddon storages may be used to supplement winter/spring baseflows to achieve flow objectives for Reach 4. If environmental water is available from the Goulburn or Campaspe systems, this may contribute to achieving ecosystem objectives in Reach 4, downstream of the Waranga Western Channel.

Environmental watering objectives for Reach 4 (SKM 2010) are presented in Table 3. Overall, priority should go to:

- bankfull flow events (three to five times per decade)
- winter minimum flows
- spring freshes
- summer freshes
- summer minimum flows.

The priority order listed above is due to Reach 4 remaining dry for the three years leading up to the 2010–11 floods. A bankfull event is required to reduce the risk of poor water quality (low dissolved oxygen, high salinity, low pH) that might be expected after prolonged drying. SKM (2010) recommends that a flow component only be implemented if it and the higher priority components could be provided into the future. This ensures supply to higher priority components before commencing a lower priority component in 2011.

3.2.2 Boort wetlands

The small volume of Commonwealth environmental water (1,700 ML as at October 2010) limits the ecosystem objectives that might be achieved in the Loddon River. If only 1,700 ML is available to the Loddon system, deployment to the Boort wetlands is recommended. Further details of the Boort wetlands and their preferred water regimes are presented in Table 4, which is based on the ecological objectives and preferred hydrological regime identified by the North Central CMA (2010b, c, d). Information on Lake Yando is provided as an example in Appendix 4. Note that Table 4 is based on the four main wetlands in the complex, for which there are current watering plans. Other wetlands in the Boort complex may also be considered for watering in the future.

Table 4: Desired filling regime of the Boort wetlands (NC CMA 2010b, c, d).

	Lake Yando	Lake Leaghur	Lake Boort	Lake Meran
Water regime	Fill and allow to dry over 18 months.	Fill and allow to dry over 18 months.	Fill with unregulated flow events from the Loddon River.	Fill and maintain as permanent for at least 9 in 10 years.
Minimum filling frequency	1 in 5 years.	1 in 5 years.		
Optimum filling frequency	1 in 3 years.	1 in 3 years.	1 in 3 years.	1 in 10 years.
Maximum filling frequency	1 in 2 years.	1 in 2 years.		
Timing	Winter–spring.	Winter–spring.	Winter–spring.	Winter–spring.
Other	Provide top-ups if there are bird breeding events.	Release a small pulse annually to maintain refuge habitat near the outfall.		Release a small pulse annually to maintain refuge habitat near the outfall.

3.3 Watering objectives under various climatic regimes

Proposed objectives and watering options for Reach 4 of the Loddon River and the Boort wetlands are presented in Table 5. Management of the flow regime for the Boort wetlands is to achieve a more natural filling and drying cycle for each wetland. This involves cycles of filling a wetland, then topping up to extend the drying phase in a subsequent year, and then followed by a dry phase. The length of each phase varies for each wetland (see NC CMA 2010b, c, d for details).

It should be noted that the scenarios for extreme dry, dry, median and wet years identified in Table 5 are only indicative of what might occur. Such categorisations infer that a particular year remains constant (i.e. a dry year remains dry) and independent from other scenarios. In reality, climatic and flow conditions can vary seasonally and annually. In addition, climatic conditions are not always indicative of flow conditions and vice versa. For example, a dry spring may be followed by a wet summer, with water availability being that of a median year overall. Climatically, conditions may be dry or extreme dry but because of water demand and delivery, flow conditions in a river may be that of a median or wet year.

In addition, the scenarios for extreme dry, dry, median and wet years identified in Table 5 do not deal with sequences of years. For example, most of the Boort wetlands being filled in 2010–11 by flood flows will not require filling again in 2011–12, regardless of the climate scenario in 2011–12. In short, specific environmental water releases such as those outlined in Table 4 may not be required in all years.

Table 5: Summary of proposed objectives for the Loddon River (Reach 4) and Boort wetlands.

	Management objectives for specific water availability scenarios			
	Extreme dry	Dry	Median	Wet
	Goal: Avoid damage to key ecological assets	Goal: Ensure ecological capacity for recovery	Goal: Maintain ecological health and resilience	Goal: Improve and extend healthy aquatic ecosystems
Water availability	Minimum allocation on record	30th percentile year	50th percentile year	70th percentile year
Loddon River				
Reach 4	No allocation will be made for the Loddon (NC CMA 2009). No releases unless a commitment can be made to supply a high-bankfull flow (3,500 ML/d for 6 days) as well as minimum winter flows. Environmental water can contribute to other releases to provide: • A bankfull flow (3,500 ML/d for 6 days). • Minimum flows in winter (100 ML/d). Carry over any excess environmental water.	No releases unless a commitment can be made to supply a winter-spring, high bankfull flow (3,500 ML/d for 6 days) as well as minimum winter flows. The winter-spring bankfull flow is to dilute and flush potentially acid water before reinstating a baseflow regime. Environmental water can be used to contribute to: • A bankfull flow (3,500 ML/d for 6 days). • Minimum flows in winter (100 ML/d). • A spring fresh of 750 ML/d for 10 days to increase flow and thus habitat variability for macrophytes and macroinvertebrates. However, the North Central CMA would seek to have arrangements in place to secure the allocations listed above in > 80% of years. Carry over environmental water if no other water is committed.	Environmental water can be used to contribute to: • Deliver a high bankfull flow (3,500 ML/d for 6 days) in spring to maintain or improve water quality and maintain and where possible rehabilitate riparian vegetation and floodplain habitats. This includes distributary channels, wetlands and the Leaghur State Forest (SKM 2010). • Deliver a winter low flow minimum of 100 ML/d (if there is sufficient water to deliver in > 80% of years) to prevent terrestrial vegetation from encroaching into the river channel. • Deliver a spring fresh of 750 ML/d for 10 days to increase flow and thus habitat variability for macrophytes and macro invertebrates. Environmental water can be used to top-up BE water to: • Contribute (if necessary) to the 3,500 ML/d for 6 days required to start flows in Reach 4. • Maintain winter baseflow at 100 ML/d May–October, inclusive. • Deliver a spring fresh of 750 ML/d for 10 days.	Environmental water can be used to contribute to: • Deliver a high-bankfull flow (3,500 ML/d for 6 days) in spring to maintain or improve water quality and maintain and where possible rehabilitate riparian vegetation and floodplain habitats. This includes distributary channels, wetlands and the Leaghur State Forest (SKM 2010). • Deliver a winter low flow minimum of 100 ML/d (if there is sufficient water to deliver in >80% of years) to prevent terrestrial vegetation from encroaching into the river channel. • Deliver a spring fresh of 750 ML/d for 10 days to increase flow and thus habitat variability for macrophytes and macroinvertebrates. Environmental water to be used to top-up BE water to: • Contribute (if necessary) to the 3,500 ML/d for 6 days required to start flows in Reach 4. • Maintain winter baseflow at 100 ML/d May–October, inclusive. • Deliver a spring (and potentially summer) fresh of 750 ML/d for 10 days.

Water availability	Management objectives for specific water availability scenarios							
	Extreme dry		Dry		Median		Wet	
	Goal: Avoid damage to key ecological assets		Goal: Ensure ecological capacity for recovery		Goal: Maintain ecological health and resilience		Goal: Improve and extend healthy aquatic ecosystems	
	Minimum allocation on record		30th percentile year		50th percentile year		70th percentile year	
Boort wetlands The small volume of Commonwealth environmental water (1,700 ML of entitlements as at October 2010, with total volume available subject to allocation) limits the ecosystem objectives that might be achieved in the Loddon River. If only 1,700 ML is available to the Loddon system, deployment to the Boort wetlands is recommended. Further details of the Boort wetlands and their preferred water regimes are presented in Table 4, which is based on the ecological objectives and preferred hydrological regime identified by the North Central CMA (2010b, c, d). Information on Lake Yando is provided as an example in Appendix 4. Note that Table 4 is based on the four main wetlands in the complex, for which there are current watering plans. Other wetlands in the Boort complex may also be considered for watering in the future.								
Lake Yando	Fill:	0.9–1.0 GL	Fill:	0.9–1.0 GL	Fill:	0.9–1.0 GL	Fill:	0.9–1.0 GL
	Top-up:	0.3 GL	Top-up:	0.3 GL	Top-up:	0.3 GL	Top-up:	0.3 GL
Lake Leaghur	Fill:	0.9–1.3 GL	Fill:	0.9–1.3 GL	Fill:	0.9–1.3 GL	Fill:	0.9–1.3 GL
	Top-up:	0.4 GL	Top-up:	0.4 GL	Top-up:	0.4 GL	Top-up:	0.4 GL
Lake Boort	Fill:	6.0–9.0 GL	Fill:	6.0–9.0 GL	Fill:	6.0–9.0 GL	Fill:	6.0–9.0 GL
	Top-up:	3.0 GL	Top-up:	3.0 GL	Top-up:	3.0 GL	Top-up:	3.0 GL
Lake Meran	Fill:	10.0–14.0 GL	Fill:	10.0–14.0 GL	Fill:	10.0–14.0 GL	Fill:	10.0–14.0 GL
	Top-up:	1.4–2.7 GL	Top-up:	1.4–2.7 GL	Top-up:	1.4–2.7 GL	Top-up:	1.4–2.7 GL

PART 2:
Water Use Strategy

4. Environmental water requirements

4.1 Baseline flow characteristics

Commonwealth environmental water in the Loddon system is available from the headworks storages for regulated river delivery down to Loddon Weir, whilst entitlements for the Goulburn and Campaspe system are potentially available from the Waranga Western Channel, which crosses the Loddon River at Loddon Weir.

The daily flow model of the Loddon River is known as the Goulburn-Broken-Campaspe-Loddon REALM model. At the time of preparing this report, this model had not been updated for several years and many of the assumptions in the model were out of date. Hence gauged flow data has been used in the information presented below.

The period of data assessed is 1976 to 2010. This period of record includes a range of climatic conditions including the recent drought conditions and wetter conditions during the 1970s.

Table 6 and Table 7 show that the river has no flow in an extreme dry year. This reflects the very recent drought years. 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 Serpentine Weir below 20 ML/d over the historical period). Flows at Serpentine Weir, upstream of the Waranga Western Channel, are considerably higher than flows downstream of the channel due to irrigation deliveries to the Boort Irrigation Area via the channel. Current flows may be higher than historical flows, due to the introduction of minimum passing flows in the Loddon River (Environmental Reserve) Bulk Entitlement (BE) Order 2005. Note that the values in Table 6 and 7 are derived independently for each month. In the extreme dry year in particular, Table 6 and 7 highlight that zero flows can occur each month of the year but this does not necessarily mean that zero flows persist for the whole year.

Table 6: Streamflows (ML/d) for the Loddon River at Serpentine Weir (1976–2010).

Month	Extreme dry year (minimum on record)	Dry year (30th percentile daily flow)	Median year (50th percentile daily flow)	Wet year (70th percentile daily flow)
Jul	0	20	51	161
Aug	0	30	106	411
Sep	0	53	186	501
Oct	0	42	176	492
Nov	0	32	121	270
Dec	0	30	90	237
Jan	0	37	131	288
Feb	0	41	236	505
Mar	0	45	625	861
Apr	0	48	205	500
May	0	22	66	149
Jun	0	18	45	70

Table 7: Streamflows (ML/d) for the Loddon River downstream of Loddon Weir (1976–2010).

Month	Extreme dry year (minimum on record)	Dry year (30th percentile daily flow)	Median year (50th percentile daily flow)	Wet year (70th percentile daily flow)
Jul	0	7	12	67
Aug	0	7	14	133
Sep	0	7	11	214
Oct	0	7	10	46
Nov	0	6	9	13
Dec	0	5	7	12
Jan	0	5	7	11
Feb	0	6	8	12
Mar	0	6	8	12
Apr	0	6	8	11
May	0	7	9	30
Jun	0	7	13	39

4.2 Environmental water demands

4.2.1 Loddon River from Loddon Weir to Kerang Weir (Reach 4)

Section 3 of this document outlines that the aim for delivering water in the Loddon River is to provide a bankfull flow of 3,500 ML/d for six days in spring, in Reach 4. This should occur three to five times per decade. After this flow component has been provided, a winter baseflow of 100 ML/d can be delivered, provided it can be delivered in more than 80 per cent of years. When these winter baseflows are reliably provided, a spring fresh of 750 ML/d for 10 days every year (except bankfull flow years) can be delivered.

The volume required to deliver this bankfull event depends on unregulated flows in the river and the ability to enhance a natural flood event. SKM (2010) reports that flows above 3,500 ML/d in spring have occurred with a frequency of around 70 events per 100 years and flows above 750 ML/d in spring occur, on average, once per year (although in some years multiple events occur while in other years no events may occur). The range of volumetric requirements at the delivery site is shown in Table 8 for each desired event.

For the bankfull flow downstream of Loddon Weir, up to 19,300 ML would be required to extend historical events above the flow threshold to the desired event duration. Daily shortfalls in providing this event to the desired duration would have ranged up to 3,382 ML/d.

For the spring fresh event downstream of Loddon Weir up to 6,500 ML would be required to extend historical events above the flow threshold to the desired event duration. Daily shortfalls in providing this event to the desired duration would have ranged up to 730 ML/d.

For the winter baseflow following the bankfull flow of the previous year, part of the baseflow will already be provided under the Loddon River bulk entitlement. If the volume in the Loddon headworks storages is greater than 60,000 ML, then 61 ML/d is provided in this Reach. If the volume in storage is less than 60,000 ML, then 20 ML/d is provided in this Reach. That is, of the required flow of 18,200 ML over the six month winter period (May to October), a minimum of 3,600 ML would be provided under the bulk entitlement if the Loddon storages are below 60,000 ML and a minimum of 11,100 ML would be provided if they are above 60,000 ML. Natural runoff events will also provide some periods of baseflow above the target 100 ML/d. Taking these factors into account, it is estimated that in any given year, the volume required to address the shortfall on this target baseflow volume could range from 1,200 ML to 14,700 ML. These volumes are specified at the delivery site and exclude river losses, which can be as high as 40 per cent of the released volume, as discussed further in section 6.2.1.

Table 8: Range of event volumes required at the delivery site to achieve desired environmental flows in Reach 4.

Desired flow event	Event volume required to piggyback natural events			
	Extreme dry	Dry	Median	Wet
Bankfull flow of 3,500 ML/d for 6 days in Loddon R d/s Loddon Weir	0–19,300 ML		0–18,900 ML	
Winter baseflow of 100 ML/d(1)	2,200–14,700 ML		1,200–7,200 ML	
Spring fresh of 750 ML/d for 10 days in Loddon R d/s Loddon Weir	n/a	0–6,500 ML	0–5,900 ML	

n/a indicates that event is not expected to be provided under these climate conditions.

(1) extreme dry and dry conditions assume Loddon storages drop below 60,000 ML in the winter following the bankfull flow event (which triggers a reduction in minimum flows under the bulk entitlement) and therefore represent an upper bound demand that would be lower if storages remain above 60,000 ML.

4.2.2 Boort wetlands

The volumes required to either fill or top up the Boort wetlands at the delivery site is presented in Table 5 (section 3.3).

5. Operating regimes

5.1 Introduction

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

- Identifying the target environmental flow recommendations for the coming season.
- Defining triggers to commence and cease delivering those recommended flows.
- Identifying any constraints on water delivery, such as available airspace in irrigation channels, 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 flow recommendations in each of the different climate years is triggered by storage volume in the Loddon headworks storages (Cairn Curran Reservoir, Tullaroop Reservoir and Laanecoorie Reservoir) as shown in Table 9. This trigger is based on the Loddon River environmental flow triggers in Loddon River (Environmental Reserve) Bulk Entitlement (BE) Order 2005 (as amended).

Table 9: Identifying seasonal target environmental flow recommendations.

Climate year for selecting flow recommendations	Storage volume in Loddon headworks storages	Events provided in preceding year
Extreme dry	Less than or equal to 60,000 ML[1]	None
Dry		Bankfull
Medium	Greater than 60,000 ML[2]	N/a
Wet		N/a

(1) the target flow recommendations for extreme dry and dry years differ slightly. The target flow recommendations for dry years incorporate an additional spring fresh requirement (of 750 ML/d). The provision of this requirement is dependent on flow provisions in the preceding year. If flow provisions in the preceding year permit, the dry year objectives should be targeted, otherwise the extreme dry year objectives should be targeted.

(2) the target flow recommendations for medium and wet years are the same.

5.3 Delivery triggers

Proposed operational triggers for delivering the suggested environmental flow proposals are presented in Table 10.

The 3,500 ML/d bankfull event is the first target flow to reset the ecosystem. No other flow proposals are provided unless this bankfull event has occurred. The ability to deliver this event using environmental entitlements is limited by the outlet capacity of upstream storages and the Waranga Western Channel (discussed further in sections 5.4 and 5.5). Any contribution from environmental water entitlements to the bankfull event will be triggered by a naturally occurring event above that flow threshold. The travel time from Laanecoorie Reservoir to downstream of Loddon Weir, where the proposal is suggested, is approximately two to three days (see Section 5.7). This means that by monitoring flows downstream of Loddon Weir, there would be sufficient time to extend a naturally occurring event to the desired six day duration if the monitored flow is expected to remain above 3,500 ML/d for at least two to three days and environmental water managers are only planning to extend the event by a short duration. The circumstances under which a contribution from environmental water holdings could be made would be if:

(i) Cairn Curran Reservoir is spilling but Tullaroop Reservoir is not or vice versa, in which case releases from the reservoir below capacity can be timed to match or augment the flood peak from the spilling reservoir.

(ii) Cairn Curran and Tullaroop Reservoirs are below capacity and a flood peak is generated from unregulated tributaries upstream of Laanecoorie Reservoir, such as from Bet Bet Creek or McCallum Creek. Releases can be made from either reservoir to match or augment the flood peak from these tributaries.

(iii) A flood peak is generated on tributaries downstream of Laanecoorie Reservoir and releases from Laanecoorie Reservoir can help to extend the duration of the flood.

(iv) Waranga Western Channel deliveries are used to augment a flow peak as it passes through Loddon Weir, regardless of its origin.

The delivery of the 100 ML/d baseflow proposal in all years occurs continuously over the season specified in the flow proposals. This flow is within channel and can be delivered from the Loddon headworks storages. This flow can also be delivered to Reach 4 via the Waranga Western Channel if sufficient water is not available from the Loddon headworks storages. The delivery of this baseflow proposal shall only occur if the proposed bankfull event (3,500 ML/d) can be reliably provided in the near future or has already been provided recently (approximately within two to three years).

The delivery of the 750 ML/d spring fresh is dependent on conditions in the river in the preceding winter/spring period. This event shall only be delivered if both the baseflow (100 ML/d) and bankfull flow (3,500 ML/d) have been provided, in full, in the preceding year. If suitable conditions occurred in the preceding year, the spring fresh could be delivered to extend naturally occurring events. If an event has not commenced by the end of October, an event can be created. This flow is within channel and can be delivered via the Loddon River. Additional flow can also be delivered via the Waranga Western Channel to supplement this proposal if sufficient water is not available on the Loddon system. The ability to deliver this event using Goulburn and Campaspe system entitlements is limited by the outlet capacity of the Waranga Western Channel and is discussed further in section 5.5.

Table 10: Summary of proposed operational regime for achievement of environmental objectives.

Climate year	Flow objective in Loddon River (Reach 4)	Season/ Timing	Average return period	Trigger for delivery	Trigger for ceasing delivery
Extreme dry	100 ML/d	May–Oct	All extreme dry years.	Maintain throughout season.	n/a.
	3,500 ML/d for 6 days	Aug–Nov		• Commence delivery from Loddon headworks to augment naturally occurring bankfull event if natural duration is expected to be less than 6 days at d/s Loddon Weir. • Augment delivery with water from the Waranga Western Channel.	n/a.
Dry, Medium and Wet	100 ML/d	May–Oct	All dry, medium and wet years.	Maintain throughout season	n/a.
	750 ML/d for 10 days	Aug–Nov		• Commence delivery from Loddon headworks to augment naturally occurring event if natural duration is expected to be less than 10 days at d/s Loddon Weir. • Augment delivery with water from the Waranga Western Channel as required. • Deliver full event by 31 October. Whichever occurs earliest. Only deliver if both baseflow (100 ML/d) and winter/spring bankfull (3,500 ML/d) were provided in full in the preceding year.	n/a.
	3,500 ML/d for 6 days	Aug–Nov		• Commence delivery from Loddon headworks to augment naturally occurring bankfull event if natural duration is expected to be less than 6 days at d/s Loddon Weir. • Augment delivery with water from the Waranga Western Channel.	n/a.

5.4 Storage releases

The delivery of environmental water from storages may be constrained by the following storage release capacities:

Tullaroop Creek

- The release capacity of Tullaroop Reservoir is 450 ML/d when below full supply level. This may constrain deliveries to Tullaroop Creek below Tullaroop Reservoir.

Loddon River downstream of Cairn Curran Reservoir

- The release capacity of Cairn Curran Reservoir is 1,600 ML/d when below full supply level. This may constrain the ability to deliver high and overbank flows to the Loddon River downstream of Cairn Curran Reservoir.
- Note that water can be released from the spillway gates once storage in the reservoir exceeds 30 per cent of capacity. Release capacity is approximately 35,000 ML/d when the reservoir is at 40 per cent capacity and approximately 140,000 ML/d when the reservoir is at 100 per cent capacity (the flooding impacts of such release rates need to be considered, see Section 5.8).

Loddon River downstream of Laanecoorie Reservoir

- The release capacity of Laanecoorie Reservoir is 1,300 ML/d for regulated supply. This may constrain the ability to deliver high and overbank flows to the Loddon River downstream of Laanecoorie Reservoir.
- High flow rates released from Cairn Curran (such as high flows released through the spillway gates) will flow over the Laanecoorie Reservoir spillway.

5.5 Channel capacity

Waranga Western Channel capacity constraints can occur seasonally. The channel does not operate from mid-May to mid-August. During this time, Goulburn-Murray Water (G-MW) undertakes maintenance. Historically, the channel operates every second winter to supply the Wimmera-Mallee channel system, however with pipelining this will no longer be required. Approximate spare delivery capacities (ML/d) in the reach of the Waranga Western Channel upstream of the Loddon River are shown in Figure 3. Other reaches of the channel can also be constrained, particularly between Waranga Basin and the Campaspe siphon, however this reach is considered indicative of constraints between the Campaspe siphon and Loddon Weir. The data in Figure 3 is shown as a range of spare channel capacity over a range of allocations around the defined climate years.

This figure highlights, for example, that in an extreme dry year there can be in the order of 100–450 ML/d spare capacity in the channel, with the channel potentially operating at full capacity in spring. In a wet year it is possible that the channel will operate at full capacity throughout the irrigation season. Access to spare capacity in the channel is likely to be more limited in dry and median years than in extreme dry and wet years.

It should be noted that the irrigation demand pattern has changed significantly in recent (drought) years and the long term future pattern is unclear. This is not reflected in past analysis underpinning Figure 3. Hence the use of the Waranga Western Channel is an uncertain delivery path. G-MW should be consulted if the Waranga Western Channel is to be used to deliver environmental water, to check the likelihood of spare capacity in the channel at any given time.

Local capacity constraints within the irrigation channel system west of the Loddon River can also be a constraint to the delivery of water to the Boort wetlands. Delivery of water to the Boort wetlands via the channel system should be discussed in advance with G-MW to determine potential delivery times.

If environmental water managers want to use the channel system during the non-irrigation season, they need to consult with G-MW well in advance of the end of the irrigation season to determine whether deliveries via the channel system can be maintained during the non-irrigation season. To use this option, casual user charges apply, as well as operational loss (of water) associated with running the channel from its own entitlement.

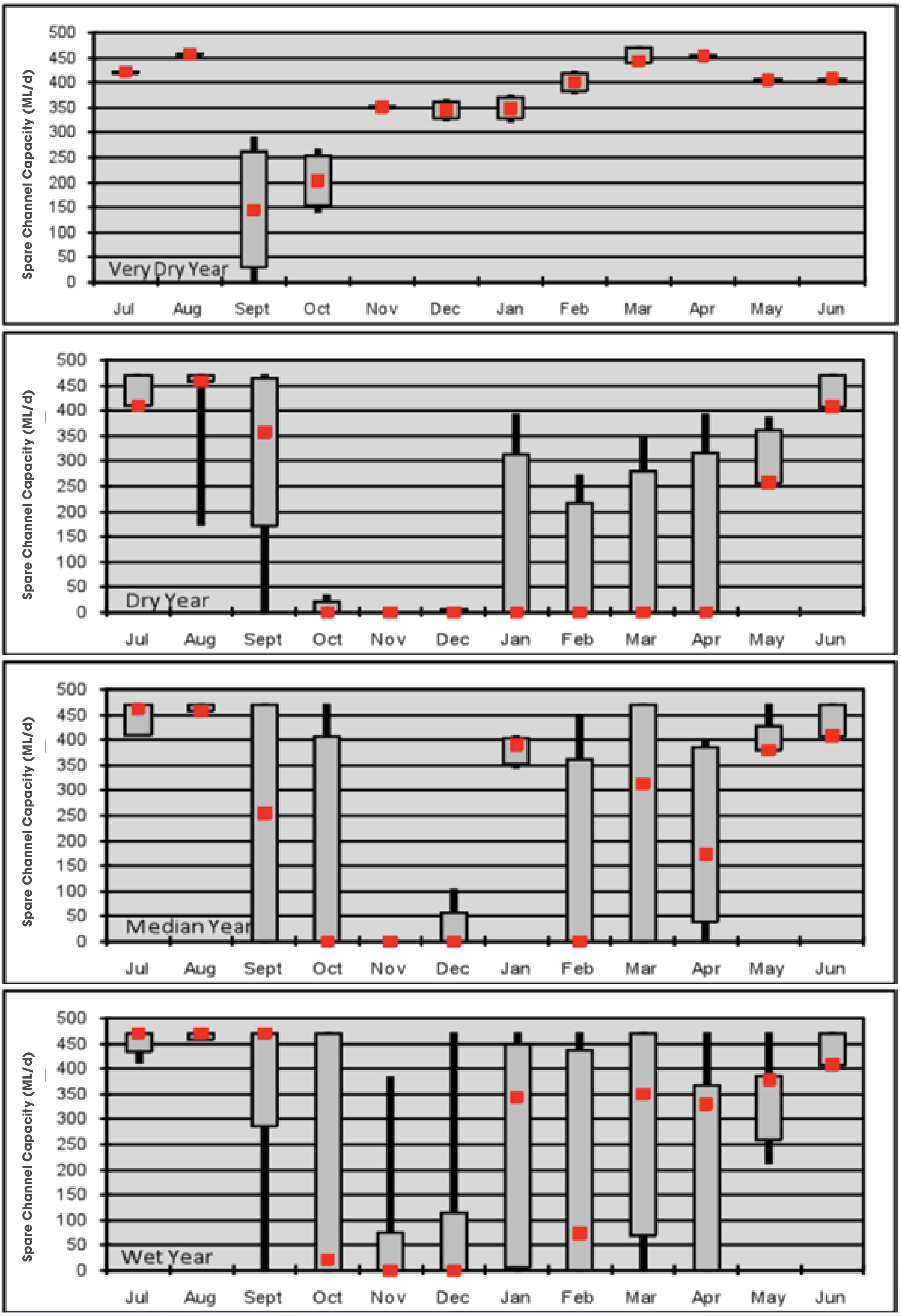

Figure 3: Spare channel capacity in the Waranga Western Channel upstream of Loddon Weir, 1895–2009.

5.6 Weir flow control

The delivery of low environmental flow recommendations (such as summer low flows) can be limited by the ability of weirs, particularly Bridgewater Weir and Kerang Weir, to regulate low flows (SKM 2006). Further details of reliably regulated flow thresholds were not presented in SKM (2006).

Low flow control at Serpentine Weir has traditionally been limited; however, a small, remotely-operated door system has recently been fitted to improve flow control at low rates.

5.7 Travel time

Two runoff events in October and November of 2000 were analysed to gain an appreciation of travel times along the Loddon River. For these events, which peaked at 3,000 – 5,000 ML/d downstream of Serpentine Weir, travel time was in the order of two to three days from Laanecoorie Reservoir to Loddon Weir, with a further six day travel time from Loddon Weir to Appin South. By the time the flood event had passed through Kerang Weir pool, it was unrecognisable as a flood peak due to attenuation and mixing with regulated flows from Pyramid Creek. This is shown in Appendix 1.

For deliveries using the channel system, G-MW requires an order four days in advance to guarantee the delivery (although order times are expected to decrease with modernisation). The implication is that if a runoff event occurs in the Loddon River, there is a limit to the operational flexibility to order additional water from the Goulburn and Campaspe systems to supplement the natural event. This is because the travel time along the Goulburn/Campaspe Rivers and then along Waranga Western Channel is longer than the travel time along the Loddon River from Laanecoorie Reservoir to Loddon Weir. However, if a rainfall event occurs, orders for water are likely to be cancelled and water in transit in the channel system plus water in balancing storages such as Tandarra pondage may be able to be called upon. This would allow environmental water managers to use Waranga Western Channel water from the Goulburn and Campaspe systems for long duration events where four day forecasts indicate the likely need for top-up of the natural flow event from the channel system.

5.8 Flooding

River channel capacities are generally not a constraint to delivering the proposed environmental flows. The thresholds for significant flooding at key locations are summarised in Table 11. These thresholds are in excess of the proposed environmental flows at these sites.

Table 11: Thresholds for significant flooding (SKM 2006).

Location	Threshold for Significant Flooding
Tullaroop Creek below Tullaroop Reservoir	5,000 ML/d (bankfull capacity)
Loddon River downstream of Cairn Curran Reservoir	21,000 ML/d
Loddon River downstream of Serpentine Weir	10,000 ML/d – breakout towards Butchers Lagoon
Loddon River downstream of Loddon Weir	5,000 ML/d – breakout towards Kelshes Lagoon
Loddon River downstream of Kerang Weir	4,000 ML/d

Whilst river channel capacities are generally not a constraint to delivering the proposed environmental flows, between Loddon Weir and Kerang Weir higher flows break out of the main river channel into a series of anabranches and distributary channels. The capacity of the main river channel decreases significantly to approximately 300 ML/d downstream of The Chute. This means that the proposed spring fresh for Reach 4 (750 ML/d) would be expected to engage the distributary channel system. Figure 4 shows the location of key features and distributary channels of the lower Loddon River.

The largest of these distributary channels are:

- Kinypanial Creek.
- Venables Creek.
- Twelve Mile Creek.
- Wandella Creek.

The commence-to-flow thresholds of these distributary channels are uncertain due to regular changes in channel morphology and the complexity of the channel system. Additionally, water loss along this reach of the river is believed to be high, particularly during dry conditions, however the magnitude of loss is uncertain. Further investigations are required to determine likely flow paths and loss at different delivery rates through this reach of the Loddon River.

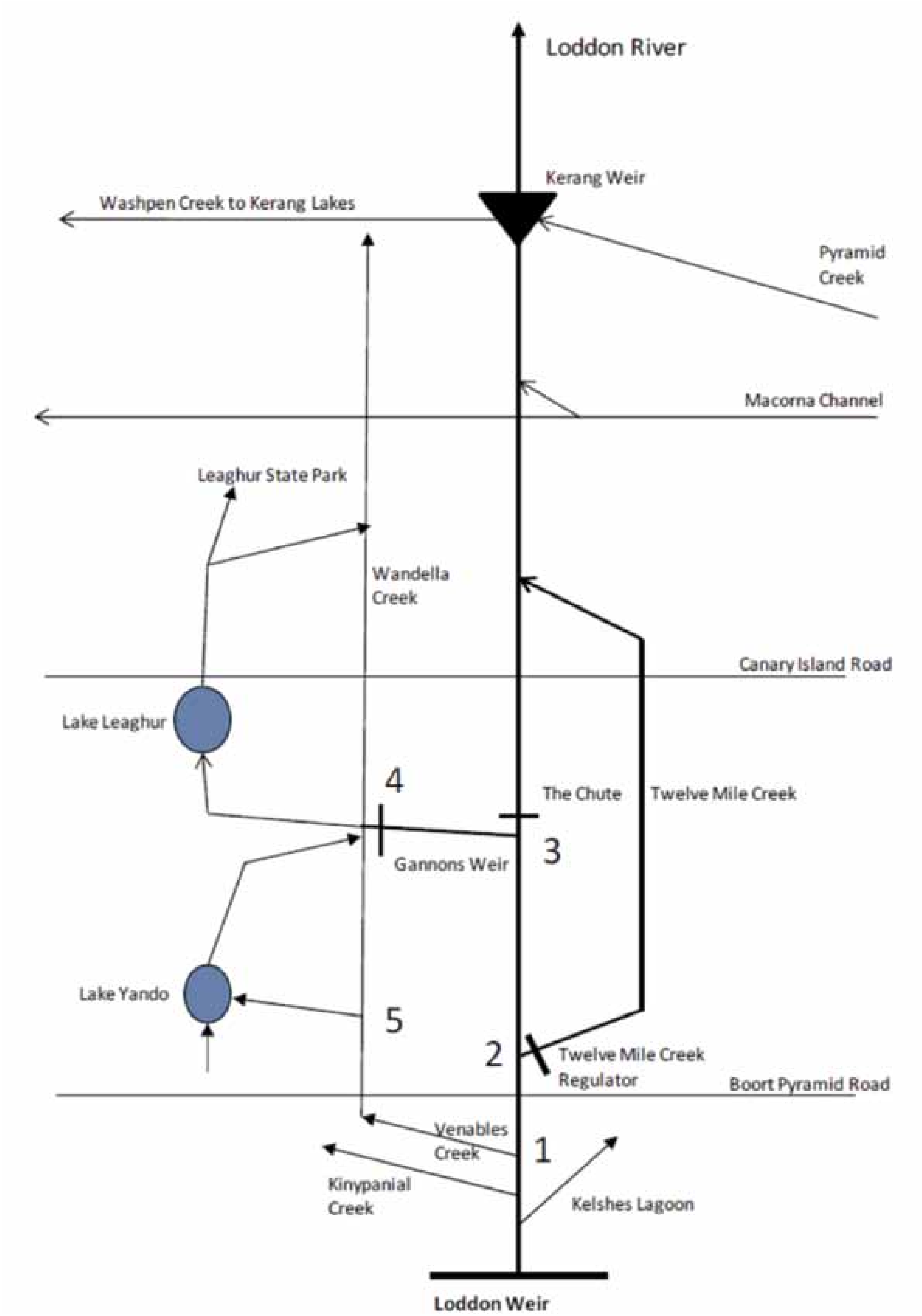

Figure 4: A schematic diagram showing the location of key features and distributary channels of the lower Loddon River (SKM 2010).

5.9 Water delivery costs

5.9.1 Delivery costs

There are no delivery costs if water is delivered via the river system. However, any water delivered via the Waranga Western Channel from the Goulburn or Campaspe systems would attract additional fees.

If water for Boort district wetlands is ordered from the Waranga Western Channel system, then the following charges apply in 2011–12: $200 per service point plus $7.85 per ML. This information can be found on G-MW's website http://www.g-mwater.com.au/customer-services/feesandcharges. Note that delivery and storage charges are subject to review on an annual basis.

5.9.2 Carryover costs

G-MW charges per megalitre for water share transferred from the spillable water account to an allocation bank account for the Goulburn, Campaspe and Murray systems. These charges do not currently apply to the Loddon system (where spillable water accounts are not available).

5.10 Interactions with other assets

The Loddon River system is hydraulically connected to the Kerang Lakes system and the Murray River system (discharging to the Murray River system downstream of Torrumbarry Weir). Water can be delivered to these hydraulically connected assets via the Loddon River, however, high losses along the lower Loddon River between Loddon Weir and Kerang Weir, particularly at high flows, limits this opportunity.

Entitlements held in the Goulburn and Campaspe systems can also be used to deliver water to the Loddon River downstream of Loddon Weir.

6. Governance and planning arrangements

6.1 Delivery partners, roles and responsibilities

The major strategic partners in delivering water to assets with the Loddon system include:

- Victorian Environmental Water Holder, is responsible for making decisions on the use of Victorian environmental water.
- North Central CMA, as the environmental water manager for the Loddon system.
- G-MW, as the BE holder and manager of the major reservoirs in the catchment, manager of the Pyramid-Boort Irrigation Area and also the licensing authority responsible for groundwater and surface water licensed diversions.

Both the North Central CMA and G-MW cooperate with the GB CMA and the VEWH in the delivery of environmental water, particularly in relation to water transfers from the Goulburn and Campaspe systems.

6.2 Approvals, licenses, legal and administrative issues

6.2.1 Water shepherding and return flows

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:

- There is adequate rigour in the calculation and/or measurement of return flows.
- The return flows meet relevant water quality standards.
- Additional losses (if any) are taken into account.
- The return flows can be delivered in line with the timing requirements of the downstream user, purchaser or environmental site.
- The system operator can re-regulate the return flows downstream, with a known and immaterial spill risk, if the entitlement holder is requesting credits on a regulated system (DSE 2009).

The Commonwealth Government does not currently have the ability to deliver water from its water shares for the Loddon system, so it must transfer its allocations to the VEWH for them to be used. If the Commonwealth Government transfers its allocations to the environmental entitlements held by the VEWH then the ability to reuse those flows in the Murray River depends on the conditions of the individual entitlements.

Gaining credits in the Torrumbarry system for water delivered down the Loddon River could be difficult as losses in the Loddon River downstream of Loddon Weir are very high with numerous distributaries heading both east and west from the river channel. Flow gauging accuracy is low at high flows in this area, which further compounds uncertainty in estimating losses. DSE has estimated losses in its monthly GSM REALM model using gauged flows along the Loddon River. This loss is both high and very uncertain. Losses between Loddon Weir and Appin South (approximately half way along Reach 4) is defined in a function contained in Schedule 2 of the environmental entitlement for the Loddon River, and is capped at 40 per cent of the flow immediately downstream of Loddon Weir. Losses downstream of Appin South (to Kerang Weir) and losses along the distributary systems are not well understood.

If water is delivered from the Loddon headworks, it can only be delivered in the regulated river section of the Loddon River, which ends at the Loddon Weir pool. Downstream of the Loddon Weir pool is a different trading zone and flows are considered unregulated. According to G-MW (A. Shields, G-MW, pers. comm. 1/12/10), water ordered from the Loddon headworks storages can be delivered via the Loddon River to an ordering point immediately downstream of Loddon Weir. Beyond this point, the water cannot be shepherded through to Kerang Weir as private diverters can access the water (see also section 7).

If the water shares held in the Loddon headworks storages are used to augment winter low flows, spring fresh and bankfull events in the Loddon River, it is likely that demands from private diverters downstream of Loddon Weir will be low. This means that any flow events upstream of Loddon Weir that environmental water has contributed to are likely to pass downstream without being diverted by consumptive users. The exception to this will be in the first fresh or winter low flow after a dry autumn and winter, when private diverters will want to refill their dams. Environmental water managers should liaise further with G-MW to better understand any potential shepherding of environmental flows along this reach in the future.

6.3 Trading rules and system accounting

6.3.1 Water trading

Victorian and southern NSW water trading zones are shown in Figure 5 and Table 12 summarises trading capabilities between zones.

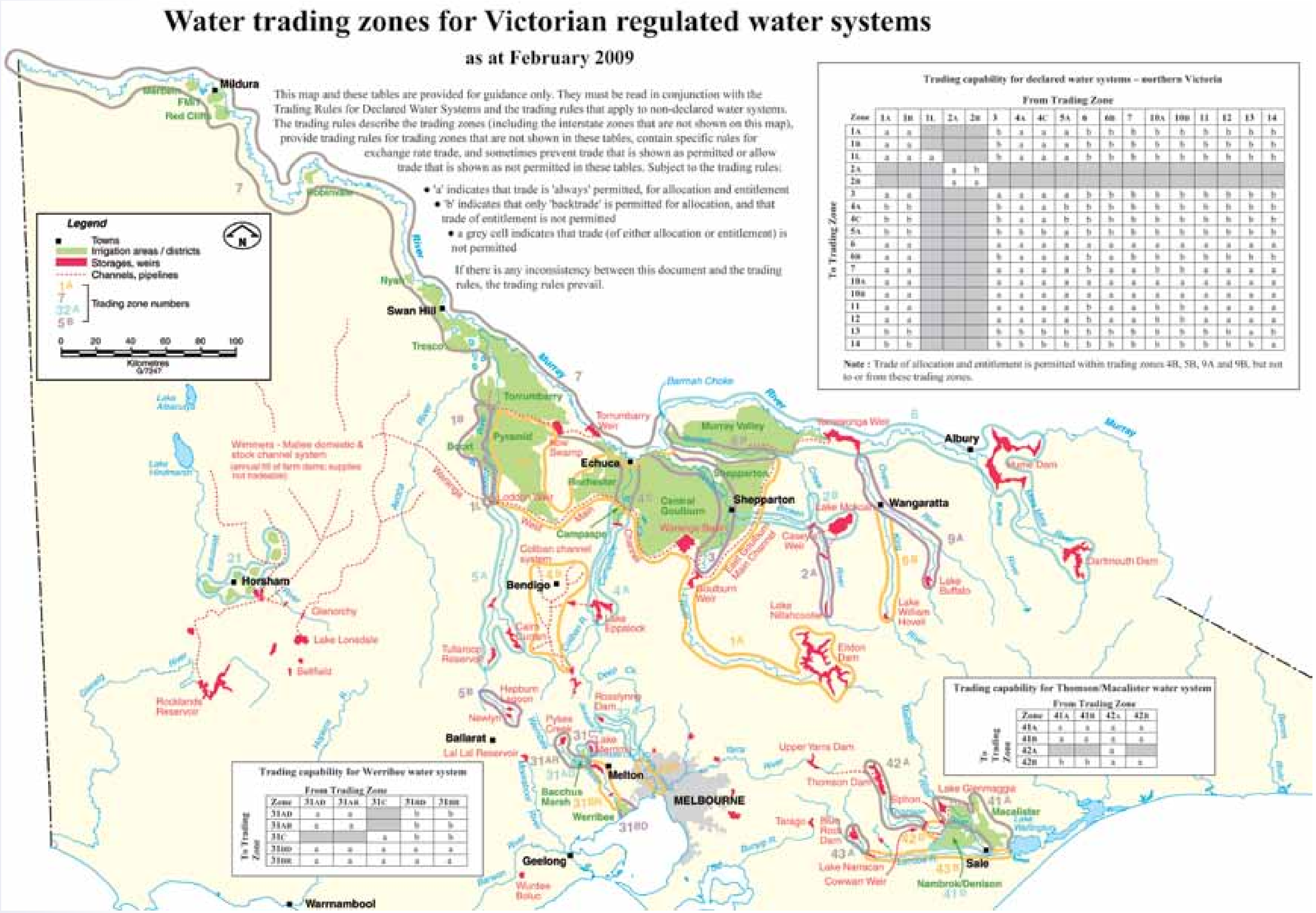

Figure 5: Victorian and southern NSW water trading zones and trading capability (Source: http://waterregister.vic.gov.au/Public/Documents/trading_zones_map.pdf).

The Loddon River system down to but not including Loddon Weir is located in Trading Zone 5A, the Loddon Weir pool is located in Trading Zone 1L and the Loddon River between Loddon Weir and Kerang Weir is located in Trading Zone 1B.

Table 12: Summary of trading rules between zone

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

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

Additional Trading Rules

All trade, except to unregulated tributaries, is with an exchange rate of 1.00. Trade into the unregulated river zones of the Loddon (zones 150 and 151) can only be transferred as a winterfill licence, which becomes available in the following year. The water share volume is increased by 19 per cent when transferred to a winterfill licence, and decreased by 19 per cent when bought from a winterfill licence. Trading into Murray Irrigation Limited areas (zone 10B) attracts a 10 per cent loss of share volume.

Permanent trade is currently limited to 4 per cent per year from irrigation districts in Victoria. G-MW advises via media releases when these limits are reached for individual irrigation districts. There are various exemptions for this limit specified in the trading rules on the Victorian Water Register (http://waterregister.vic.gov.au/).

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

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

This means that environmental water managers must make any allocation trades well in advance of a targeted runoff event.

Water trading attracts water trading fees. If water trading is undertaken without the use of a broker, the fees are currently less than $80 for a Victorian intrastate State trade. See the Victorian Water Register for Victorian fee schedules at http://www.waterregister.vic.gov.au/Public/ApplicationFees.aspx.

6.3.2 Water storage accounting

Water storage accounting for the Loddon system is annual water accounting (July to June) with limited carryover.

Carryover on the Loddon System is limited to a maximum volume of 50 per cent of the water holder's high-reliability water shares and 50 per cent of the water holders low reliability water shares (note that unused allocation is carried over against high reliability water shares first). On 1 July each year, 5 per cent is deducted from the carryover volume for evaporation loss.

The maximum volume that can be held in a water holder's allocation bank account is 100 per cent of their entitlement. This means that if a water holder carries over 50 per cent against their high-reliability water shares at the start of the season (July 1), the water holder's allocation bank account will hold 47.5 per cent (50 per cent carryover less (5 per cent x 50 per cent carryover volume) for evaporation). Once the current season allocations reach 52.5 per cent (i.e. total water holdings reach 100 per cent), no further allocation improvements will be credited to the allocation bank account, regardless of whether the account is drawn down in the current year. Therefore, carrying over water will only be of value if next season's allocations are expected to be less than 100 per cent, or if early season allocations are expected to be low and environmental watering is required.

Please note that carryover arrangements on the Loddon River system are currently under review by DSE.

More information on carryover can be accessed at http://www.g-mwater.com.au/customer-services/carryover/lbbcarryover/.

7. Risk assessment and mitigation

Risks associated with the delivery of environmental water to both the Loddon River and Boort wetlands are summarised in Table 13 and Table 14. 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. A framework for assessing risks has been developed by SEWPaC and is included at Appendix 6.

Table 13: Risk associated with water delivery in the Loddon system.

Risk type	Description	Likelihood	Consequence	Risk level	Controls
Acid sulfate soils	Acid sulfate soils suspected in Reach 4 of the Loddon River.	Possible, depending on rainfall received. Greater likelihood in drier conditions with lower river levels.	Major	Medium	Do not operate this reach unless a large flow event occurs in winter-spring.
Salinity	Water salinity in the Loddon River can exceed 1,500 EC, which is a threshold often used to indicate increased risk to aquatic organisms. The extent to which additional releases contribute to or exacerbate salinity problems should be considered as releases from the Loddon storages are contemplated. Releases from the Goulburn via Waranga Western Channel are of good quality and are unlikely to pose a salinity risk at the volumes proposed.	Possible	Minor	Low	Monitor salinity of water delivered to the assets. Seek alternative sources of water should water quality be deemed to increase risks associated with salinity.
Blackwater	Blackwater events have been recorded with the release of water after prolonged dry or low flow periods in Reach 4.	Unlikely – Likely, depending on antecedent conditions.	Moderate	Medium	Ensure flow releases are of sufficient magnitude and duration to avoid blackwater after periods of low or no flow. Also ensure routine flows to prevent litter build-up.
River red gum incursion	Wetting and drying of the river channel (e.g. in Reach 4) provides conditions that may favour the incursion of river red gum. Over time, the growth of trees can alter the hydraulics and geomorphology of the channel.	Likely	Moderate	Medium	Survey river red gum saplings that have survived recent (2010) floods. Review the need to implement physical (or other) control mechanisms.
Other considerations	Flooding of private land.	Possible	Minor	Low	Coincide releases with water delivered via Waranga Western Channel to avoid localised flooding below Cairn Curran. Evaluate the potential for flooding of private land along Reach 4 with bankfull discharge.

Table 14: Risk associated with water delivery in the Boort wetlands.

Risk type	Description	Likelihood	Consequence	Risk level	Controls
Acid sulfate soils	No known issues at wetland sites.	Unlikely	Major	Medium	Survey wetlands during dry phase to find any evidence of ASS.
Salinity	Water salinity levels in the environmental water provided from the Loddon River (particularly during times of drought) or Waranga Western Channel for the Boort wetlands could pose a risk to salinity levels at these assets: • The extent to which additional releases contribute to or exacerbate salinity problems should be considered at the time that releases from the Loddon storages are contemplated. • Releases from the Goulburn via Waranga Western Channel are of good quality and are unlikely to pose a salinity risk at the volumes proposed.	Unlikely	Minor	Low	Monitor salinity of water delivered to the assets.
Invasive species	Carp and mosquito fish may invade with inflows.	Likely	Moderate	Medium	Install carp screens on inlet channels.
Blackwater	May occur when rewetting after prolonged dry period.	Unlikely – Likely, depending on antecedent conditions.	Moderate	Medium	Regular provision of environmental water will help to minimise the build up of organic matter. Time deliveries to occur when temperatures are low.
Water loss	Water losses are likely when refilling dry wetlands.	Likely	Minor	Medium	Allow for losses when estimating allocations to individual sites.
Other considerations	Flooding of private land. Risk of flooding in Reach 4 needs to be considered and managed.	Possible	Minor	Low	Plan delivery for times when there is capacity in the Western Waranga Channel and releases from Cairn Curran Resevoir are not to exceed 1600 ML/d.

8. Environmental water reserves

8.1 Environmental water holdings and provisions

8.1.1 Water planning responsibilities

The Northern Region Sustainable Water Strategy (NRSWS) provides the strategic direction for water management across northern Victoria (DSE 2009). Responsibilities for the planning and delivery of water specified by the Loddon Bulk Entitlements are shared between G-MW and the North Central CMA, in collaboration with DSE and the VEWH.

Commonwealth environmental water in the Loddon system can be delivered from the Loddon headworks storages (Cairn Curran or Tullaroop Reservoirs). There is also the potential to deliver water shares in the Goulburn system to the lower Loddon system (downstream of Loddon Weir) via the Waranga Western Channel when spare capacity is available.

8.1.2 Environmental water provisions

Minimum passing flow requirements are specified in Schedule 1 to the Bulk Entitlement (Loddon River – Environmental Reserve) Order 2005 (as amended) and are summarised in Table 15. The minimum passing flow requirements must be provided first under Clause 10.1 of G-MW's entitlement.

Table 15: Minimum passing flow requirements in bulk entitlements for the Loddon River.

Reach	Season	Requirements
Reach 1: Loddon River – Cairn Curran Dam to Laanecoorie Reservoir.	Nov – Apr	Minimum flow of 20 ML/d or natural*.
	Nov – Apr	Fresh flow of 35 ML/d for 7 consecutive days, 4 per season or natural.
	May – Oct	Minimum flow of 35 ML/d or natural if storage in Cairn Curran and Tullaroop Reservoirs is > 60,000 ML. Minimum flow of 20 ML/d or natural if storage in Cairn Curran and Tullaroop Reservoirs is ≤ 60,000 ML.
Reach 2: Tullaroop Creek – Tullaroop Dam to Laanecoorie Reservoir.	All year	Minimum flow of 10 ML/d or natural.
	Nov – Apr	Fresh flow of 13.5 ML/d for 7 consecutive days, 4 per season or natural.
Reach 3a: Loddon River – Laanecoorie Reservoir to Serpentine Weir.	Nov – Jul	Minimum flow of 15 ML/d or natural.
	Aug – Oct	Minimum flow of 52 ML/d or natural if storage in Cairn Curran and Tullaroop Reservoirs is > 60,000 ML. Minimum flow of 15 ML/d or natural if storage in Cairn Curran and Tullaroop Reservoirs is ≤ 60,000 ML.
	Nov – Apr	Fresh flow of 52 ML/d for 13 consecutive days, 3 per year or natural.
Reach 3b: Loddon River – Serpentine Weir to Loddon Weir.	Nov – Apr	Minimum flow of 19 ML/d or natural.
	May – Oct	Minimum flow of 61 ML/d or natural if storage in Cairn Curran and Tullaroop Reservoirs is > 60,000 ML. Minimum flow of 19 ML/d or natural if storage in Cairn Curran and Tullaroop Reservoirs is ≤ 60,000 ML.
	Nov – Apr	Fresh flow of 61 ML/d for 11 consecutive days, 3 per season or natural.
Reach 4: Loddon River – Loddon Weir and Kerang Weir.	Nov – Apr	Minimum flow to be varied over a cyclical two week period; rising from 7 ML/d to 12 ML/d in the first week, falling from 12 ML/d to 7 ML/d in the second week (plus losses).
	May – Oct	Minimum flow of 61 ML/d (plus losses) if storage in Cairn Curran and Tullaroop Reservoirs is > 60,000 ML. Minimum flow of 20 ML/d (plus losses) if storage in Cairn Curran and Tullaroop Reservoirs is ≤ 60,000 ML.
	Jan – Feb	Fresh flow of 40 ML/d (plus losses) for 14 consecutive days.

*'or natural' refers to minimum flows (below the prescribed minimum flows) that would occur naturally, for example with low catchment inflows during dry periods. Allowing discharge to fall below the prescribed flow to what would occur naturally under dry conditions will help to retain part of the natural variability of the flow regime.

8.1.3 Current water holdings

Commonwealth environmental water holdings (as at October 2010) are summarised in Table 16. Note: Loddon water shares can be used in the Loddon River directly. Water shares from the Goulburn and Campaspe systems can only be used if sufficient channel capacity to deliver the entitlements is available in the Waranga Western Channel, as the Commonwealth environmental water holdings do not include delivery shares.

Volumes of Commonwealth environmental water are constantly being updated. For the latest figures see www.environment.gov.au/ewater.

Table 16: 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
	0.0	
Goulburn	64,919.6	High reliability water share
	10,480.0	Low reliability water share
Broken**	0.0	
	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**

* Commonwealth environmental water includes 70.0 ML of regulated river entitlement on the Ovens System; however this water cannot be traded outside of the Ovens Basin.

** Commonwealth environmental water includes 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.

*** The Commonwealth environmental water holdings include 20,820 ML of supplementary water shares on the Murrumbidgee System; however this water cannot be traded outside of Murrumbidgee system.

Environmental water currently held under Bulk Entitlements by the VEWH are summarised in Table 17.

Table 17: Environmental water currently held under Bulk Entitlements by the VEWH.

Water holding	Volume	Specifications
Boort District Wetland Entitlement Bulk Entitlement (Loddon River – Environmental Reserve) Order 2005.	2,000 ML	High reliability water share. Can be supplied to Lake Meran, Little Lake Meran, Lake Boort, Lake Yando, Lake Leaghur or other priority wetlands.
'Sales Package' (unbundling of prior water rights) Bulk Entitlement (Loddon River – Environmental Reserve) Conversion Amendment Notice 2007.	2,105 ML	Low reliability water share. Non-specified environmental water. Can be used to deliver Loddon River environmental flows or to deliver water to the Boort district wetlands.
Wimmera-Mallee Pipeline Savings Entitlement Bulk Entitlement (Loddon River – Environmental Reserve) Amendment Order October 2010.	7,490 ML	Availability assessed on 1 July each year. Available in full if Goulburn system allocation in April of the previous year was 1 per cent or greater. 0 ML available if Goulburn system allocation in April of the previous year was less than 1 per cent. Only available for use downstream of Loddon Weir.

8.2 Seasonal allocations

Loddon system seasonal allocation in Schedule 3 of G-MW's entitlement is a function of the Goulburn system allocation unless there is a local water shortage. Figure 6 and Figure 7 provide a summary of October and April seasonal allocations, indicative of spring and autumn water availability, for the Loddon, Goulburn and Campaspe systems respectively. This information is sourced from the MSM-Bigmod post-TLM run (#22061).

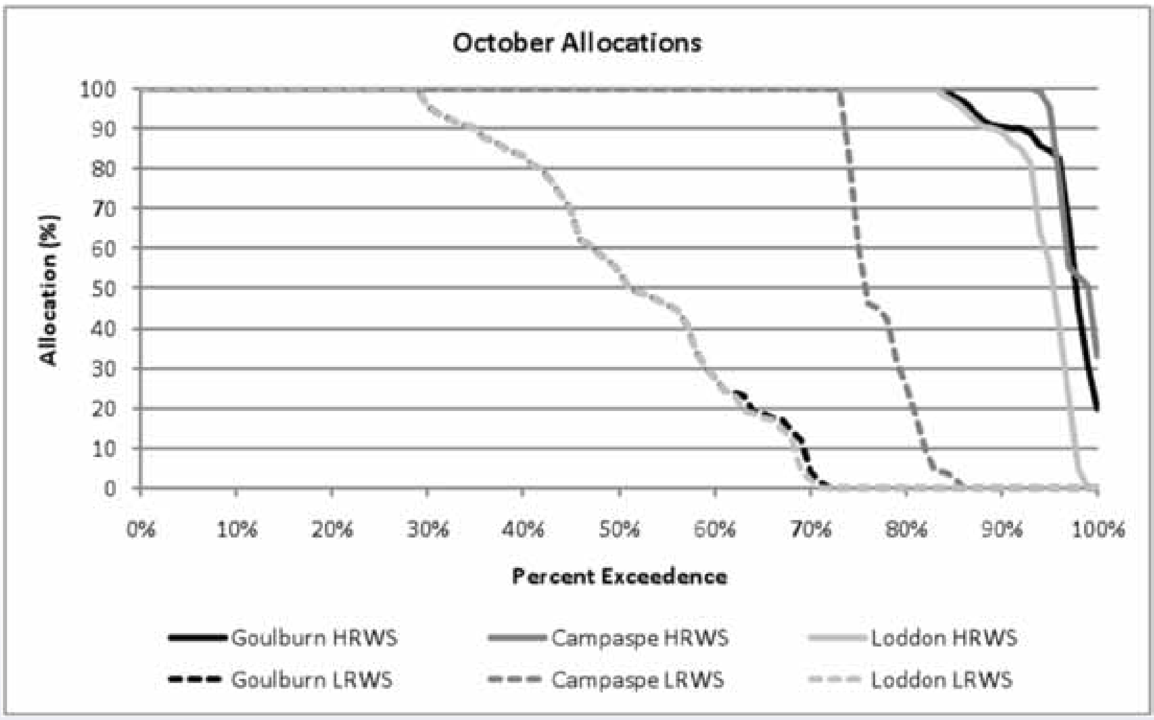

Figure 6: October seasonal allocations for the Loddon, Goulburn and Campaspe systems.

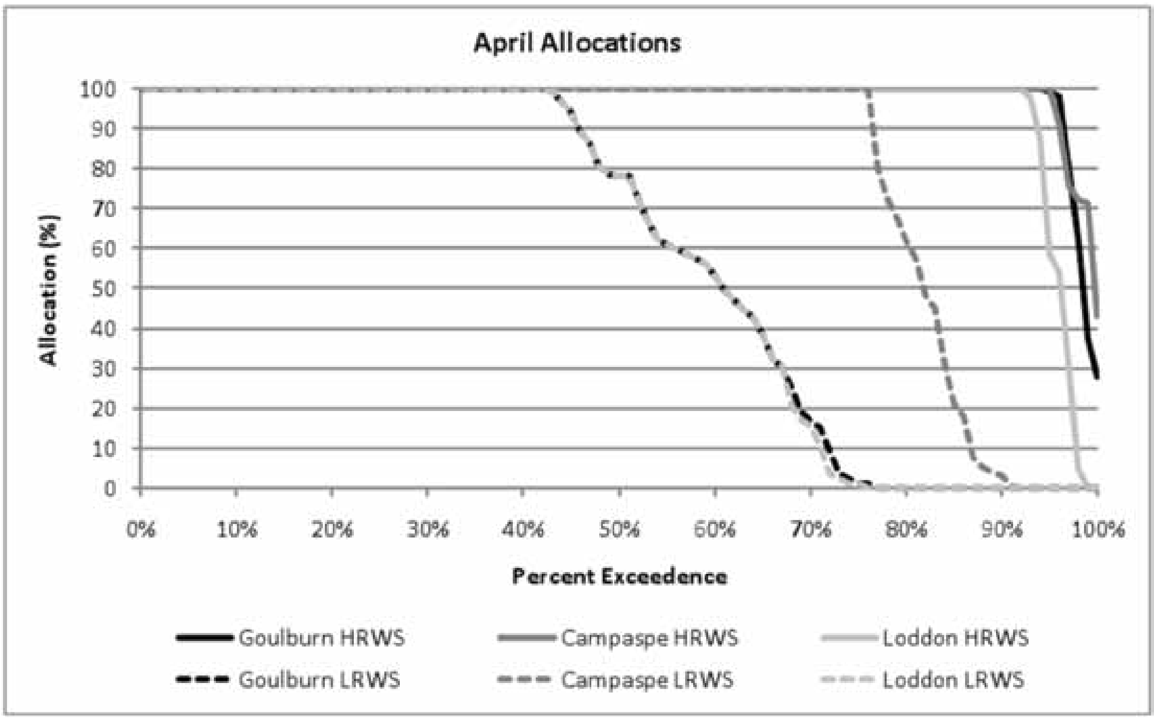

Figure 7: April seasonal allocations for the Loddon, Goulburn and Campaspe systems.

The allocation expected to be available (in terms of announced allocation) to the environment under different climate conditions is summarised in Table 18. The corresponding volume of water expected to be available to the environment under different climate conditions is summarised in Table 19.

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 scenario. Tables 18 and 19 were produced by SKM using allocation information from MSM-Bigmod with TLM deliveries in place (run #22061).

The tables show that no water is expected to be available in the Loddon system in an extreme dry year. It would be expected that in spring of a wet year there would be 100 per cent of high reliability water shares and 96 per cent of low reliability water shares (1,700 ML based on October 2010 holdings) available.

Table 18: Likely announced allocation 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	100
Broken	High reliability water share	20.0	1	96	97	98	1	100	100	100
	Low reliability water share	4.2	0	0	0	0	0	100	100	100
Campaspe	High reliability water share	5,124.1	33	100	100	100	43	100	100	100
	Low reliability water share	395.4	0	100	100	100	0	100	100	100
Loddon	High reliability water share	1,179.0	0	100	100	100	0	100	100	100
	Low reliability water share	527.3	0	2	54	96	0	16	78	100
South Australia	High reliability	43,297.4	44	100	100	155	62	100	100	102

Table 19: Likely volume available to the environment from Commonwealth environmental water holdings (as at October 2010), under different climate scenarios.

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	20.8	0.0	0.0	0.0	20.8
Goulburn	High reliability water share	64,919.6	13.0	64.9	64.9	64.9	18.2	64.9	64.9	64.9
	Low reliability water share	10,480.0	0.0	0.4	5.7	10.0	0.0	1.8	8.2	10.5
Broken*	High reliability water share	20.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Low reliability water share	4.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Campaspe	High reliability water share	5,124.1	1.7	5.1	5.1	5.1	2.2	5.1	5.1	5.1
	Low reliability water share	395.4	0.0	0.4	0.4	0.4	0.0	0.4	0.4	0.4
Loddon	High reliability water share	1,179.0	0.0	1.2	1.2	1.2	0.0	1.2	1.2	1.2
	Low reliability water share	527.3	0.0	0.0	0.3	0.5	0.0	0.1	0.4	0.5
South Australia	High reliability	43,297.4	19.0	43.3	43.3	66.9	26.6	43.3	43.3	44.3
Total below Barmah Choke			**48.1**	**247.4**	**272.3**	**328.6**	**80.8**	**278.1**	**305.6**	**329.9**
Total			**53.2**	**382.6**	**459.5**	**522.3**	**109.5**	**471.8**	**499.4**	**523.6**

* 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.

Whilst it is useful to consider water availability and potential allocations under different climatic conditions (extreme dry, dry, median, wet), it is important to recognise that conditions are not necessarily discrete or independent. It is recommended that watering options are reviewed on a seasonal basis, taking into account the outlook and developing conditions, recent water regimes and water quality conditions.

8.3 Water availability forecasts

A description of likely water availability for the Loddon, Goulburn and Campaspe systems is provided by G-MW when allocation announcements are made. Allocation announcements are generally made on the 15th of each month (or the next business day), however when allocations to high reliability water shares are less than 100 per cent 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, G-MW 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 G-MW's website (see Media Releases http://www.g-mwater.com.au/news/media-releases).

Note that in years with high water availability, only the seasonal allocation outlook can be prepared (i.e. water availability forecasts cannot be provided with allocation announcements).

PART 3:
Monitoring and Future Options

9. Monitoring, evaluation, and improvement

Assessing ecosystem response to specific environmental flow releases as a form of intervention analysis is a challenging exercise (Chee et al. 2006). Being able to apply traditional study designs (e.g. before-after-control-impact) is usually problematic, as control sites are usually lacking (i.e. there is not another Loddon River) and establishing 'before' conditions is difficult given the nature of river regulations and flows delivered from natural rainfall-runoff events. A number of monitoring and evaluation programs already exist that include the Loddon River. However, nearly all of these programs were established for purposes such as water quality and river condition reporting, rather than specifically for assessing ecosystem effects resulting from changes to the flow regime. The Victorian Environmental Flows Monitoring and Assessment Program (VEFMAP) was established specifically to assess ecosystem response to new environmental flow regimes. VEFMAP is currently being implemented across northern Victorian rivers, including the Goulburn, Campaspe and Loddon Rivers (Chee et al. 2006, SKM 2007).

The adoption of adaptive management could be useful for improving the outcomes of environmental water delivery. Adaptive management requires that the objectives, conceptual basis, implementation and evaluation of environmental releases are clearly articulated and analysed in order to learn from experience and inform future decisions. Evaluating the effectiveness of previously delivered flow events should also be the first action taken when planning for water management in subsequent years. While VEFMAP provides a useful conceptual basis and will provide long-term information on the effectiveness of environmental flow releases, it is based on longer-term objectives (e.g. five-year) across numerous rivers assuming 'typical' climatic and hydrological conditions (Chee et al. 2006). Evaluating the effectiveness of environmental water may also require dedicated short-term investigation on mechanistic responses and evaluation of water management within and among individual assets such as the Boort wetlands (i.e. smaller scale hypotheses than for VEFMAP) to provide information on which to base future decisions.

The following sections provide a guide to the parameters to be considered for future monitoring of environmental water releases. They do not provide guidance on aspects of study design, site selection and sampling frequency.

9.1 Existing monitoring programs and frameworks

SKM (2007) provided an overview of current monitoring programs that include the Loddon River. Existing information and monitoring includes:

- Cross-section surveys undertaken during environmental flow studies.
- Monthly water quality monitoring undertaken as part of the Victorian Water Quality Monitoring Network (VWQMN), as well as local monitoring of dissolved oxygen, temperature, turbidity, pH and electrical conductivity (NC CMA 2010).
- Fish surveys undertaken as part of the Murray-Darling Basin Sustainable Rivers Audit (SRA) and local investigations.
- Macroinvertebrate sampling undertaken by the Environment Protection Authority Victoria as part of its fixed sites network and as part of the SRA.

There are numerous long-term flow gauges along the Loddon River. Key streamflow gauges along the river are listed in Table 20. A full list of available streamflow gauges can be found on the Victorian Water Resources Data Warehouse (DSE 2010), which also includes monitoring sites on distributaries of the Loddon River. G-MW collects operational flow data along the Waranga Western Channel and storage volume data in the headworks storages, which can be requested directly from G-MW.

Table 20: Key flow monitoring gauges in the Loddon River catchment.

Site number	Site name	Relevance
407210	Loddon River at Cairn Curran Reservoir	E-flow Reach 1 compliance point
407248	Tullaroop Creek at Tullaroop Reservoir	E-flow Reach 2 compliance point
407229	Loddon River at Serpentine Weir	E-flow Reach 3 compliance point
407224	Loddon River downstream of Loddon Weir	Flow to lower Loddon River
407205	Loddon River at Appin South	E-flow Reach 4 compliance point
407202	Loddon River at Kerang	E-flow Reach 5 compliance point

9.2 Operational water delivery monitoring

Monitoring the delivery of environmental water along the Loddon River can be undertaken using the flow gauging sites previously listed. In addition, SEWPaC has a pro forma Operational Monitoring Report (Appendix 2) to capture information related to releases, such as event details, risk management, initial observations and other issues.

9.3 Key parameters for monitoring and evaluating ecosystem response

9.3.1 Loddon River

The proposed environmental watering objectives for the Loddon River (see section 2) relate to the delivery of flow components that support the following:

- Geomorphology:
  - Maintain channel form and processes along the main channel of the Loddon and its system of anastomosing distributaries, such as Twelve Mile Creek, Kinyapanial Creek, Bannagher Creek and Venables Creek.
- Vegetation:
  - Maintain/rehabilitate in-stream aquatic vegetation and ecological processes.
  - Control existing invasion of main channel with non-aquatic species.
  - Maintain/rehabilitate flood-dependent riparian and floodplain ecological vegetation classes (EVC).
  - Rehabilitate river-floodplain ecological interactions and ecological processes on floodplain.
- Water quality:
  - Reduce incidence and severity of blackwater events.
  - Limit impacts associated with acid sulfate soils.
- Fish:
  - Maintain pools or depressions in the bottom of the channel that fish may opportunistically use when wet.
- Macroinvertebrates:
  - Maintain habitat quality.

A detailed program to monitor and evaluate ecosystem responses to environmental flows along the Loddon River has been established as part of the VEFMAP (Chee et al. 2006) (Appendix 3). The monitoring and investigations established under VEFMAP provide a valuable starting point from which to assess ecosystem response to environmental flows, including those that may result from using environmental water.

If environmental water managers wish to evaluate specific releases of environmental water, they should liaise with VEFMAP stakeholders to establish appropriate 'before' conditions from which to assess ecosystem responses once environmental water is delivered. For details on the recommended measures and sampling regime see Chee et al. (2006). Additional monitoring could include the following (SKM 2007):

- Physical habitat surveys:
  - river cross sections
  - qualitative estimate of habitat area and velocity
  - visual estimate of substratum composition
  - woody debris load assessment.

- Water quality assessment:
  - monthly in-situ physico-chemical water quality monitoring (e.g. DO, pH, EC, temperature, suspended solids, nutrients)
  - continuous dissolved oxygen, temperature and electrical conductivity.
- Riparian and in-channel vegetation surveys.
- Adult fish surveys.

9.4 Potential monitoring gaps

VEFMAP was established to assess ecosystem responses to changes to watering regimes over time. It was not designed to assess ecosystem responses to individual or short-term flow events. The main issue for assessing the effectiveness of environmental water (in isolation) is to establish a study design that provides the best possible inference that ecosystem response is due to any particular environmental release(s). Particular attention will be required to establish the 'before' conditions to allow 'before-after' comparisons. Appropriate experimental designs are best considered once the environmental water manager determines the type for flow release(s) (e.g. baseflow, fresh, overbank flow). Monitoring considerations when planning to deliver environmental water are summarised in Table 21 (see also Appendix 3 for references to VEFMAP).

Table 21: Monitoring considerations for assessing the effectiveness of environmental water in Reach 4 of the Loddon River.

Asset/ecosystem attribute	Objective	Hypotheses and indicators	Existing monitoring	Additional monitoring required	Comments
Geomorphology	• Maintain channel form and processes along the main channel of the Loddon and its system of anastomosing distributaries.	• VEFMAP hypotheses and indicators are mostly appropriate.	• Channel form is monitored at two sites every five years, or following large events. • There is no monitoring of distributaries such as Kinyapanial Creek.	• Survey of distributaries.	• Environmental water managers may consider contributing to a channel survey to provide new baseline conditions if this has not been done since the 2010 floods.
Water quality	• Improve water quality. • Reduce incidence and severity of blackwater events. • Limit impacts associated with acid sulfate soils (ASS).	• VEFMAP does not include hypotheses related to water quality.	• Water quality is currently monitored at two sites for continuous DO, EC and temperature, as well as monthly physico-chemical parameters.	• Event-based monitoring.	• Water quality hypotheses require development to test response to the delivery of environmental water in isolation.
Riparian and in-channel vegetation	• Maintain/rehabilitate in-stream aquatic vegetation and ecological processes in main channel. • Control existing invasion of main channel with non-aquatic species. • Maintain/rehabilitate flood-dependent riparian and floodplain EVCs. • Rehabilitate river-floodplain ecological interactions and ecological processes on floodplain.	• VEFMAP hypotheses and indicators are mostly appropriate.	• Vegetation is monitored at two sites every three to five years.	• Frequency and timing of monitoring (before-after) should coincide with individual watering events should the environmental water manager seek to measure the effect of environmental water in isolation from the wider water regime.	• VEFMAP can provide baseline information for assessing effects of environmental water on vegetation. However, additional or repeated measurements may be required to provide 'before' data in light of recent (2010) flood events.
Native fish	• Maintain pools or depressions in the bottom of the channel that fish may opportunistically use when wet.	• VEFMAP hypotheses and indicators are appropriate.	• Adult fish are monitored annually at four sites.	• As above.	• As above.
Macroinvertebrates	• Maintain habitat quality.	• Some but not all VEFMAP hypotheses are suitable (e.g. hypotheses related to AusRivas are not suitable).	• No macroinvertebrate monitoring is undertaken as part of VEFMAP. Habitat is monitored at two sites every five years or after events.	• As above.	• As above.

9.4.1 Boort wetlands

Environmental watering of the Boort district wetlands seeks to meet the needs of wetland vegetation as well as provide habitat for waterbirds, fish and invertebrates (NC CMA 2010b, c, d). Recent monitoring by the North Central CMA has included a vegetation survey at many of the wetlands and establishment of photo-points to assess vegetation changes over time. The scale and frequency of monitoring at the wetlands is currently constrained by limited resources. Additional funding will be required if the full suite of activities described below is to be implemented.

Vegetation

Previous vegetation surveys and records are available for the wetlands that provide baseline data from which to evaluate any ecosystem response to environmental watering. It is recommended that this information be reviewed, and updated if necessary, prior to delivering environmental water. Monthly monitoring is recommended thereafter, to assess response over time. This could include (NCCMA 2010b, c, d):

- distribution mapping
- photo points
- species lists.

Waterbirds

Monthly monitoring as water levels fluctuate is recommended for measuring the response of bird communities captured (Baldwin et al. 2005, cited in NC CMA 2010b, c) including:

- area searches
- nest surveys.

Spring surveys are required to monitor breeding events and to inform the adaptive management of the water regime (i.e. providing top-ups to maintain water levels in order to complete breeding events). Numerous previous surveys and records are available to provide baseline data in order to evaluate the response of waterbirds to the provision of water. Databases have been compiled for each wetland and these should be updated regularly following monitoring.

Fish, amphibians and macroinvertebrates

Numerous surveys and records exist to provide baseline data from which to assess ecosystem response to watering (NC CMA 2010b, c, d). Monitoring could include (Baldwin et al. 2005, cited in NC CMA 2010b, c, d):

- Fish – electrofishing, bait trapping, seine and fyke netting.
- Amphibians – call playback, funnel trapping, drift fences and pit traps.
- Macroinvertebrates – sweep netting.

Databases have also been compiled for the wetlands (NC CMA 2010b, c) and should be updated regularly following monitoring. Monitoring results can also be used to assess the habitat availability for waterbirds, as fish, amphibians and macroinvertebrates are a significant food source for many waterbird species.

Water Quality

A monthly water quality monitoring program could include:

- electrical conductivity
- pH
- turbidity
- nutrients.

10. Opportunities

10.1 Irrigation system opportunities

Tandarra Pondage is a 2,800 ML balancing storage along the Waranga Western Channel approximately 44 kilometres upstream of Loddon Weir. This storage could potentially be used to assist in delivering water to the lower Loddon River from the Waranga Western Channel. Environmental water managers could explore options with G-MW to use water from the storage when there are channel capacity constraints upstream of the pondage. The pondage can potentially be used during the winter shutdown period. G-MW would need to program its maintenance to keep the section of channel from the pondage to Loddon Weir operational during times when environmental water deliveries are desired.

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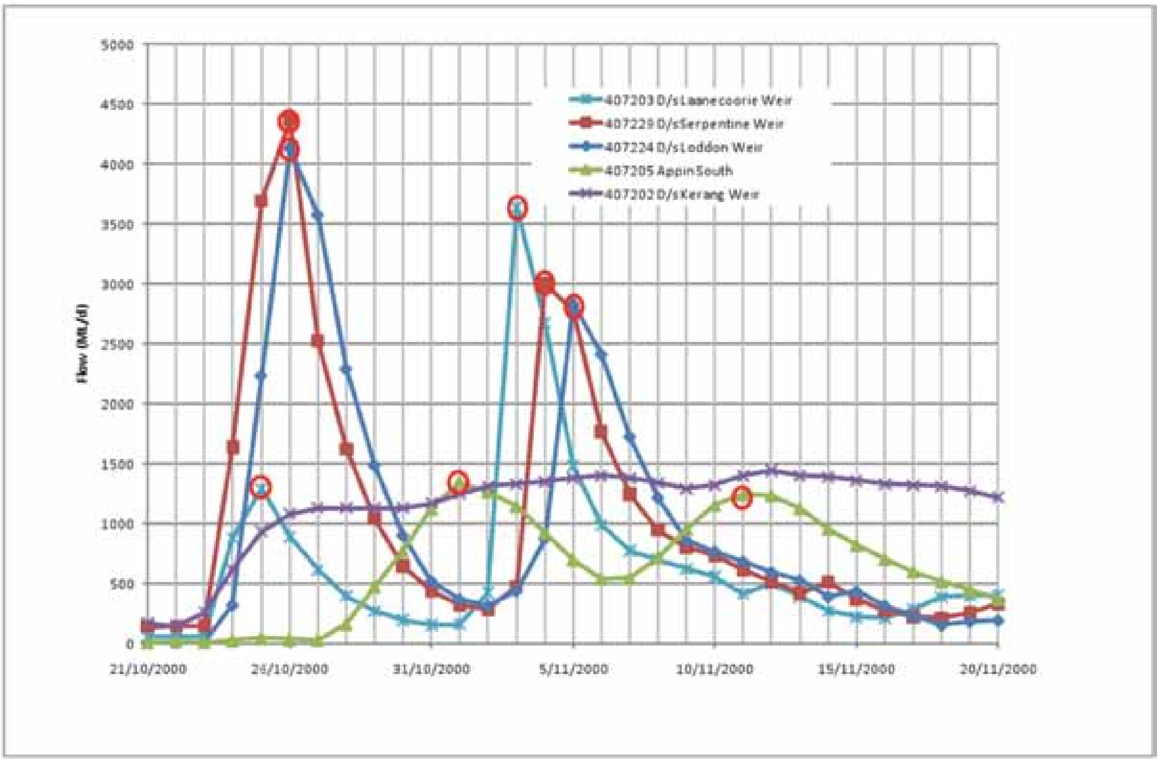
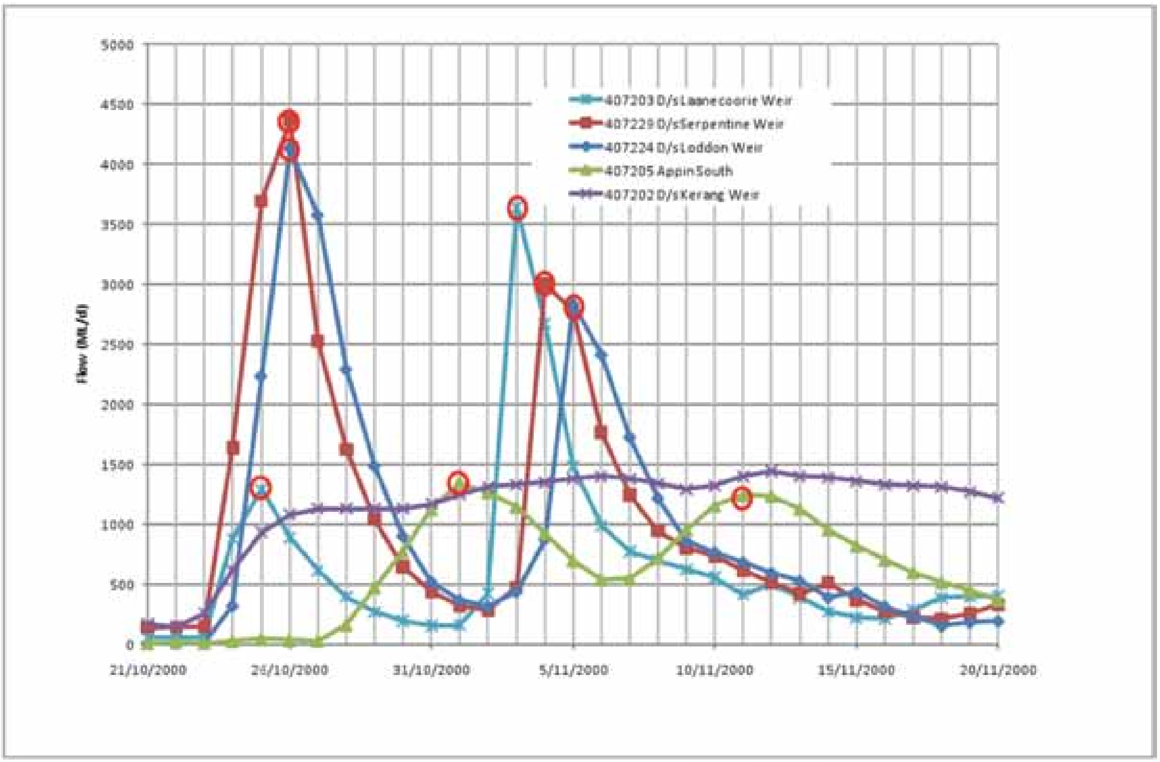
Appendix 1: Loddon River travel time





Appendix 2: Operational Monitoring Report

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 two 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 3: Summary of VEFMAP monitoring

Summary of VEFMAP monitoring arrangements for environmental water use in Reach 4 of the Loddon River (from SKM 2007, Chee et al. 2006).

Flow component	Hypotheses	Indicator(s)	Monitoring sites	Frequency	Considerations for this watering options project
Geomorphology					
Winter/spring freshes	Does increased frequency of winter-spring fresh events: a) increase the frequency of geomorphologically significant events (e.g. redistribution of bed and bank sediments)? b) increase channel complexity (e.g. areas of the stream bed which are flushed free of fine deposits, deeper pools and variability in bench elevations)? c) increase channel width and depth? d) increase rates of meander development (i.e. bank erosion on the outside bank, point bar development, increased sinuosity and eventually bend cut-off and billabong formation)?	Flow and physical habitat (channel dimensions) to assess: • Frequency of channel disturbances • Frequency of bed disturbances • Rate of bench deposition • Bed complexity • Bench development and variability • Mean channel top width, cross-section area and thalweg depth • Bank erosion on outside of meander bends • Point bar development.	Two	Every five years, event based.	VEFMAP provide baseline information for assessing effects of environmental water. May require repeat measurements to provide 'before' data if channel dimensions have not been surveyed after recent (2010) flood events.
Bankfull	As above	As above	As above	As above	As above

Flow component	Hypotheses	Indicator(s)	Monitoring sites	Frequency	Considerations for this watering options project
Habitat & macroinvertebrates					
Summer/autumn low flows and freshes	• Do implemented environmental flows maintain in-channel shallow and slow water areas? • Do implemented environmental flows maintain adequate area and depth of at least 0.1 m in shallow, slow water and riffle/run habitats? • Do implemented environmental flows maintain adequate volume and depth in permanent pools? • Do implemented environmental flows maintain connectivity? • Do implemented environmental flows maintain macroinvertebrate community structure? • Do implemented environmental flows increase fish recruitment? • Do implemented environmental flows maintain fish assemblages and/or population structure?	• Shallow and slow water area • Riffle/run depth and area • Permanent pool depth and volume • Connectivity • Number of invertebrate families index • AUSRIVAS score • SIGNAL biotic index • EPT biotic index • Presence/absence and number of 'flow-sensitive' taxa • See conceptual model for fish spawning and recruitment • Fish species composition • Relative abundance of adult/sub-adult native and exotic fish species • Population structure and size class distribution of native and exotic fish species.	Physical habitat at two sites. ***Macroinvertebrates in the Loddon are not monitored as part of VEFMAP.***	Every five years, event based.	As above VEFMAP sampling was not designed to assess short-term changes. Will require more frequent 'before' and 'after' sampling if the effects of specific watering actions are to be assessed in isolation.

Flow component	Hypotheses	Indicator(s)	Monitoring sites	Frequency	Considerations for this watering options project
Winter/spring baseflows	• Do implemented environmental flows increase in-channel shallow and slow water areas? • Do implemented environmental flows increase area of riffle and/or run habitat? • Do implemented environmental flows increase volume of permanent pool habitats? • Do implemented environmental flows result in sustained inundation of in-channel macrophytes, channel edge macrophytes, tree roots, woody debris, branch piles, in-channel bars, overhanging or undercut banks? • Do implemented environmental flows increase abundance of macrophytes? • Do implemented environmental flows improve macroinvertebrate community structure? • Do implemented environmental flows improve fish assemblages and/or population structure?	• Shallow and slow water area • Riffle and/or run area • Permanent pool depth and volume • Inundation of representative physical habitat features • See conceptual model for aquatic and riparian vegetation • Cover of submerged and amphibious species • Cover of submerged and amphibious species • Number of invertebrate families index • AUSRIVAS score • SIGNAL biotic index • EPT biotic index • Presence/absence and number of 'flow-sensitive' taxa • Fish species composition • Relative abundance of adult/sub-adult native and exotic fish species • Population structure and size class distribution of native and exotic fish species.	As above	As above	As above VEFMAP sampling was not designed to assess short-term changes. Will require more frequent 'before' and 'after' sampling if the effects of specific watering actions are to be assessed in isolation.

Flow component	Hypotheses	Indicator(s)	Monitoring sites	Frequency	Considerations for this watering options project
Winter/spring freshes	• Do implemented environmental flows increase area of riffle and/or run habitat? • Do implemented environmental flows increase volume of pool habitats? • Do implemented environmental flows result in temporary inundation of higher-level channel edge macrophytes, tree roots, woody debris, bars, benches, overhanging/undercut banks? • Do implemented environmental flows improve macro invertebrate community structure? • Do implemented environmental flows improve fish assemblages and/or population structure?	• Riffle and/or run area • Permanent pool depth and volume • Inundation of higher elevation representative physical habitat features • Number of invertebrate families index • AUSRIVAS score • SIGNAL biotic index • EPT biotic index • Presence/absence and number of 'flow-sensitive' taxa • Fish species composition • Relative abundance of adult/sub-adult native and exotic fish species • Population structure and size class distribution of native and exotic fish species.	As above	As above	As above

Flow component	Hypotheses	Indicator(s)	Monitoring sites	Frequency	Considerations for this watering options project
Aquatic & riparian vegetation					
Spring baseflow	• Do implemented environmental flows increase in-channel shallow and slow water area? • Do implemented environmental flows increase run areas? • Do implemented environmental flows result in sustained inundation of channel bed, channel edges, in-channel bars, low-lying benches, runners and anabranches in Zone A*? • Do implemented environmental flows a) increase germination and seasonal growth of submerged and amphibious fluctuation-responder species in Zone A*? b) reduce species richness of terrestrial 'dry' species in Zone A*?	• Shallow and slow water areas • Run depth and area • Inundation of geomorphic features in Zone A* • Cover of submerged and amphibious species in Zone A* • Species composition, number of submerged, amphibious and terrestrial species in Zone A* • Proportion of exotic plant species.	Two sites	Every three to five years, late spring	As above
	• What is the pattern of inundation and drying in Zones A* & B* imposed by the implemented environmental flows? • What is the composition of the resultant plant community?	• Cover of amphibious and terrestrial species in Zones A* & B* • Species composition, number of amphibious and terrestrial species in Zones A* & B* • Proportion of exotic plant species	As above	As above	As above

Flow component	Hypotheses	Indicator(s)	Monitoring sites	Frequency	Considerations for this watering options project
Spring freshes & bankfull flows	• Do implemented environmental flows wet high-level benches, upper banks, runners and anabranches in Zones B* & C*? • Do implemented environmental flows increase germination and establishment of terrestrial 'damp', terrestrial 'dry' and amphibious fluctuation-tolerator species? • Do implemented environmental flows improve canopy condition of in situ riparian trees and shrubs?	• Wetting of geomorphic features in Zones B* & C* • Species composition, number of amphibious and terrestrial species in Zones B* & C* • Proportion of exotic plant species • Germination of seedlings of overstorey and mid-storey species • Canopy condition.	As above	As above	As above
Summer baseflow	• Do implemented environmental flows maintain area of in-channel shallow and slow water and run habitats? • Do implemented environmental flows wet in-channel bars, low-lying benches, channel edges, runners and anabranches in Zone A*? • Do implemented environmental flows improve canopy condition of adjacent riparian trees and shrubs?	• See conceptual model for habitat processes • Shallow and slow water area • Run depth and area. • Wetting of geomorphic features in Zone A* • Canopy condition.	-	-	As above
Native fish					
Autumn-early winter freshes/ bankfull flows	• Do implemented environmental flows trigger spawning of diadromous fish? (Only relevant in river reaches inhabited by diadromous fish species such as galaxiids, eels and Australian grayling)	• Presence/absence of diadromous fish larvae.	-	-	VEFMAP may be appropriate for considering effects of environmental water, but it may also be difficult to separate from other influences, including recent flow history (i.e. antecedent conditions).

Flow component	Hypotheses	Indicator(s)	Monitoring sites	Frequency	Considerations for this watering options project

Winter-spring baseflows and winter-spring freshes	• Do implemented environmental flows increase overall quantity and diversity of in-stream habitat?	• See conceptual model for habitat processes
		  • Shallow and slow water area
		  • Run area
		  • Permanent pool depth and volume
		  • Inundation of physical habitat features
		  • Inundation of higher elevation physical habitat features
		  • In-channel and littoral cover of macrophytes.
			Four sites	Annually, November–April	As above

Spring-early summer bankfull flows	• Do implemented environmental flows inundate low-lying runners and anabranches to create increased slackwater habitat? • Do implemented environmental flows increase the number of fish completing larval stages?	• Area of slackwater habitat in runners and anabranches • Density of post-larval fish.	Four sites	Annually, November–April	As above

Spring-early summer base flows	• Do implemented environmental flows provide appropriate conditions for spawning and larval production of 'low flow specialist' and generalist fish species?
	• Do implemented environmental flows maintain adequate in stream habitat for adult and larval fish?
	• Do implemented environmental flows increase the number of fish completing larval stages?
		• Presence/absence of 'low flow specialist' and generalist fish larvae
		• See conceptual model for Habitat Processes
		  • Shallow and slow water area
		  • Run area
		  • Permanent pool depth and volume
		  • Connectivity
		• Density of post-larval fish.
			Four sites	Annually, November–April	As above

Flow component	Hypotheses	Indicator(s)	Monitoring sites	Frequency	Considerations for this watering options project
Spring-early summer overbank flows	• Do implemented environmental flows inundate low-lying runners and anabranches to create increased slackwater habitat? • Do implemented environmental flows inundate floodplain areas to create increased slackwater habitat? • Do implemented environmental flows provide appropriate conditions for spawning and larval production of 'flood specialist' non-diadromous fish species? • Do implemented environmental flows increase the number of fish completing larval stages?	• Area of slackwater habitat in runners and anabranches • Area of slackwater habitat in floodplain • Presence/absence of 'flood specialist' non-diadromous fish larvae • Density of post-larval fish.	Four sites	Annually, November–April	As above

Summer-autumn low flows	• Do implemented environmental flows maintain adequate in-stream habitat for adult and larval fish?
	• Do implemented environmental flows increase the number of fish completing larval stages?
		• See conceptual model for habitat processes
		  • Shallow and slow water area
		  • Run area
		  • Permanent pool depth and volume
		  • Connectivity
		• Density of post-larval fish.
			Four sites	Annually, November–April	As above

Flow component	Hypotheses	Indicator(s)	Monitoring sites	Frequency	Considerations for this watering options project
Water Quality					
All components (year-round)	• No specific hypotheses	Colour, dissolved organic carbon, dissolved reactive phosphorus, electrical conductivity, total Kjeldahl nitrogen, oxidised nitrogen, pH, total phosphorus and turbidity.	Two sites	Continuous DO, EC and temperature. Monthly physico-chemical measurements.	Dedicated monitoring program may be required, depending on the water quality variable to be tested.

*Zone A: From mid-channel to stream margin (or the area covered by water during times of baseflow).

Zone B: From stream margin to a point mid-way up the flank of the bank (or the point that is infrequently inundated).

Zone C: From mid-way up the flank of the bank to just beyond the top of the bank.

Appendix 4: Recommended Objectives and Hydrological regime for Lake Yando (NC CMA 2010b)

Ecological Objective	Justification	Hydrological Requirement
1. Habitiat Objectives		
1.1 Maintain the health and restore the distribution of river red gum (EVC 292) • Maintain health of existing trees • Provide opportunities for recruitment in the western half of the wetland	River red gum trees provide hollows, fallen branches and shading for habitat, and provide a source of seed for recruitment.	Inundate to FSL (87.59m AHD[10]) one in three years and allow natural draw-down over approximately five months.
1.2 Maintain open water and associated mudflat habitat in sections of the wetland	Provides habitat for waterbirds e.g. Australiasian Shoveler, Intermediate Egret, Eatern Great Egret, Hardhead, Musk Duck, Little Egret, Glossy Ibis.	Inundate to a minimum depth 50cm one in three years.
1.3 Maintain the health and restore the distribution of the fringing Riverine Chenopd Woodland (EVC 103) • Maintain health of existing trees • Provide opportunities for recruitment	Black Box trees provide hollows, fallen branches and shading for habitat (e.g. White-bellied Sea-Eagle and Grey-crowned Babbler), and provide a source of seed for recruitment.	Inundate to 87.8m AHD one in six years for two to three months
1.4 Maintain health and restore the distribution of Tangled Lignum vegetation across a greater range of elevations at Lake Yando	Tangled Lignum provides habitat for waterbirds e.g. Whiskered Tern, Freckled Duck	Inundate to 87.8m AHD one in six years for two to three months.
1.5 Restore diverse aquatic and amphibious plant species communities in the Galgai microtopography.	Provide a range of micro-habitats to support a diverse array of plants, birds, frogs and invertebrates.	Inundate one in three years.
2. Species/Community Objectives		
2.1 Restore habitat for the rare Winged Water-starwort	Provide the habitat to support and expand the population of this rare plant species.	Little appears to be known about water requirements.
2.2 Restore feeding and breeding opportunities for waterbirds, frogs and invertebrates	Linked to habitat objectives. Providing a variety of habitat types and high productivity of micro and macro-invertebrates and plant species through a wetting and drying cycle should enable breeding opportunities.	Fill to FSL (87.59m AHD) in spring and inundate for seven to ten months.
2.3 Ensure a viable seed and egg bank is maintained	Seed and egg banks provide a source of survival for invertebrates and macrophytes in temporary wetlands during dry periods. These habitat and food sources in turn support higher order consumers such as waterbirds, frogs and fish.	Duration variable and seasonally dependant but maintain inundation for a minimum of three months one in three years.

Desired water regime

A desired water regime has been defined for Lake Yando and is presented on the previous page.

The proposed regime aims to reinstate an intermittent water regime at a wetland that has largely been dry since 1997 except for the 2010–11 flooding events.

Timing: Winter/spring

Frequency of wetting:

Minimum: one in five years.
Optimum: one in three years.
Maximum: one in two years.

Duration: Variable (habitat dependent). Approximately five months in Red Gum Swamp (EVC 292) vegetation allowing for natural draw-down, two to three months in areas of black box and tangled lignum vegetation (EVC 103: Riverine Chenopod Woodland). Top-ups may be required to maintain duration depending on the waterbird breeding response.

Extent and depth: Dependent on objective targeted.

- Inundate the base of wetland to a minimum depth of 50 centimetres for longer than three months, for river red gums and establishment of aquatic/amphibious plant species.
- Inundate entire wetland into black box and tangled lignum areas for two to three months. Depth not important.
- Allow draw-down via evaporation (duration of approximately five months unless top-ups are required in response to waterbird breeding) facilitating the exposure of mudflat habitat with receding water levels.

Variability: High (target levels and corresponding duration).

Appendix 5: Important species recorded in the Loddon river and Boort wetlands

Loddon River

Lower Loddon River (Laanecoorie Reservoir to the Murray River) threatened species list

Species name	Common name	EPBC status	Migratory species	Presence*	FFG listing **
Flora					
Amphibromus fluitans	River swamp wallaby-grass	V		May	-
Austrostipa metatoris		V		Likely	-
Austrostipa wakoolica		E		Likely	-
Cullen parvum	Small scurf-pea	-		Known	L
Cullen tenax	Tough scurf-pea	-		Known	L
Lepidium monoplocoides	Winged pepper-cress	E		Likely	L
Maireana cheelii	Chariot wheels	V		Likely	-
Pimelea spinescens subsp. spinescens	Plains rice-flower	CE		May	L
Swainsona murrayana	Slender darling-pea	V		Likely	L
Swainsona plagiotropis	Red darling-pea, red Swainson-pea	V		Known	L
Invertebrates					
Synemon plana	Golden sun moth	CE		Known	L
Fish					
Bidyanus bidyanus	Silver perch			Known	L
Craterocephalus fluviatilis	Murray hardyhead	V		May	L
Maccullochella peelii peelii	Murray cod	V		Known	L
Macquaria australasica	Macquarie Perch	E		Known	L
Melanotaenia fluviatilis	Crimson-spotted rainbowfish	-		Known	L
Amphibians					
Litoria raniformis	Growling Grass Frog, Southern	V		Known	L
Reptiles					
Aprasia parapulchella	Pink-tailed worm-lizard	V		Likely	L
Delma impar	Striped legless lizard	V		Likely	L

Species name	Common name	EPBC status	Migratory species	Presence*	FFG listing **
Birds					
Anseranas semipalmata	Magpie goose	-		Known	L
Apus pacificus	Fork-tailed swift	-	Marine	May	-
Ardea alba	Great egret, white egret	-	Marine / wetland	May	-
Ardea ibis	Cattle egret	-	Marine / wetland / terrestrial	May	-
Gallinago hardwickii	Latham's snipe, Japanese snipe	-	Wetland	May	-
Grus rubicunda	Brolga	-		Known	L
Haliaeetus leucogaster	White-bellied sea-eagle	-	Terrestrial	Likely	L
Hirundapus caudacutus	White-throated needletail	-	Terrestrial	May	-
Lathamus discolor	Swift Parrot	E		Likely	L
Leipoa ocellata	Malleefowl	V	-	Likely	L
Merops ornatus	Rainbow bee-eater	-	Terrestrial	May	-
Pedionomus torquatus	Plains-wanderer	V	-	Likely	L
Polytelis swainsonii	Superb parrot	V		May	L
Pomatostomus temporalis temporalis	Grey-crowned babbler	-		Known	L
Rostratula australis	Australian painted snipe	V		May	L
Rostratula benghalensis s. lat.	Painted snipe	-	Wetland	May	-
Stictonetta naevosa	Freckled duck	-		Known	L
Xanthomyza phrygia	Regent honeyeater	E	Terrestrial	May	L
Mammals					
Nyctophilus timoriensis (South-eastern form)	Greater long-eared bat	V		May	L

E Endangered
CE Critically endangered
L Listed (threatened)
V Vulnerable
* The presence of species has been ascertained through:
EPBC Act, Protected Matters Search Tool website
Department of Sustainability and Environment, **Biodiversity Interactive Map** website
Victorian Department of Sustainability and Environment (2007) Advisory List of Threatened Vertebrate Fauna in Victoria – 2007. Department of Sustainability and Environment, East Melbourne, Victoria.
** Department of Sustainability and Environment (2005) Advisory List of Rare or Threatened Plants in Victoria – 2005. Victorian Department of Sustainability and Environment, East Melbourne, Victoria.
Victorian Department of Sustainability and Environment (2009) Advisory List of Threatened Invertebrate Fauna in Victoria – 2009. Department of Sustainability and Environment, East Melbourne, Victoria.

Boort wetlands

Lake Boort threatened species list

Species	Common name	EPBC status	Migratory (EPBC)	Presence	FFG listing*	Source**
Fish						
Maccullochella peelii peelii	Murray cod	V		May	✓	EPBC
Macquaria australasica	Macquarie Perch	E		May	✓	EPBC
Amphibian						
Litoria raniformis	Growling Grass Frog, Southern	V		Known	✓	NCCMA EPBC DSE
Reptile						
Delma impar	Striped legless lizard	V		Known	✓	EPBC
Ramphotyphlops proximus	Woodland blind snake	V		Known		NCCMA DSE
Birds						
Apus pacificus	Fork-tailed swift		✓	May		EPBC
Ardea alba	Great egret, white egret		✓	Known		NCCMA EPBC
Ardea ibis	Cattle egret		✓	May		EPBC
Ardea modesta	Eastern great egret		✓	Known		DSE
Gallinago hardwickii	Latham's snipe, Japanese snipe		✓	Known		NCCMA EPBC DSE
Haliaeetus leucogaster	White-bellied sea-eagle		✓	Likely	✓	EPBC DSE
Hirundapus caudacutus	White-throated needletail		✓	May		EPBC
Lathamus discolor	Swift Parrot	E		Known	✓	NCCMA EPBC DSE
Leipoa ocellata	Malleefowl	V		Likely	✓	EPBC
Merops ornatus	Rainbow bee-eater		✓	May		EPBC
Oxyura australis	Blue-billed duck			Known	✓	NCCMA DSE
Pedionomus torquatus	Plains-wanderer	V		Likely	✓	EPBC
Pimelea spinescens subsp. spinescens	Plains rice-flower	CE		May	✓	EPBC
Polytelis swainsonii	Superb parrot	V		May	✓	EPBC
Pomatostomus temporalis temporalis	Grey-crowned babbler			Known	✓	NCCMA DSE

Species	Common name	EPBC status	Migratory (EPBC)	Presence	FFG listing*	Source**
Porzana pusilla palustris	Baillon's crake			Known	✓	NCCMA DSE
Rostratula australis	Australian painted snipe	V		May	✓	EPBC
Rostratula benghalensis s. lat.	Painted snipe		✓	May		EPBC
Sterna caspia	Caspian tern		✓	Known	✓	NCCMA DSE
Stictonetta naevosa	Freckled duck			Known	✓	NCCMA DSE
Xanthomyza phrygia	Regent honeyeater	E	✓	May	✓	EPBC
Mammal						
Nyctophilus timoriensis (South-eastern form)	Greater long-eared bat	V		May	✓	EPBC

V Vulnerable

E Endangered

CE Critically endangered

* FFG Listing under the provisions of Part 3 of the *Flora and Fauna Guarantee Act 1988*

** Source EPBC: EPBC Act, Protected Matters Search Tool website (accessed 18 July 2011)

DSE: Department of Sustainability and Environment, Biodiversity Interactive Map website (accessed 18 July 2011).

NCCMA: NCCMA (2010). Lake Boort Environmental Watering Plan. Prepared for the Northern Victoria Irrigation Renewal Project, North Central Catchment Management Authority, Huntly, Victoria.

Lake Leaghur

Lake Leaghur threatened species list

Species	Common name	EPBC status	Migratory (EPBC)	Presence	FFG listing*	Source**
Flora						
Amphibromus fluitans	River swamp wallaby-grass	V		May		EPBC
Lepidium monoplocoides	Winged pepper-cress	E		Likely	✓	EPBC
Maireana cheelii	Chariot wheels	V		Likely		EPBC
Swainsona murrayana	Slender darling-pea	V		Likely	✓	EPBC
Fish						
Craterocephalus fluviatilis	Murray hardyhead	V		May	✓	EPBC
Maccullochella peelii peelii	Murray cod	V		May	✓	EPBC
Macquaria australasica	Macquarie Perch	E		May	✓	EPBC
Tandandus tandanus	Freshwater catfish			Known	✓	NCCMA
Amphibians						

Species	Common name	EPBC status	Migratory (EPBC)	Presence	FFG listing*	Source**
Litoria raniformis	Growling Grass Frog, Southern	V		Likely	✓	EPBC
Reptile						
Delma impar	Striped legless lizard	V		Known	✓	NCCMA EPBC
Birds						
Ardea ibis	Cattle egret		✓	May		EPBC
Gallinago hardwickii	Latham's snipe, Japanese snipe		✓	May		EPBC
Hirundapus caudacutus	White-throated needletail		✓	May		EPBC
Pedionomus torquatus	Plains-wanderer	V		Likely	✓	EPBC
Polytelis swainsonii	Superb parrot	V		May	✓	EPBC
Rostratula australis	Australian painted snipe	V		May	✓	EPBC
Rostratula benghalensis s. lat.	Painted snipe		✓	May		EPBC
Apus pacificus	Fork-tailed swift		✓	May		EPBC
Ardea alba	Great egret, white egret		✓	Known		EPBC
Xanthomyza phrygia	Regent honeyeater	E	✓	May	✓	EPBC
Acrocephalus stentoreus	Clamorous reed warbler		✓	Known		NCCMA
Ardea intermedia	Intermediate egret		✓	Known	✓	NCCMA
Chthonicola sagittata	Speckled warbler			Known	✓	NCCMA
Egretta garzetta	Little egret			Known	✓	NCCMA
Melanodryas cucullata cucullata	Hooded robin			Known	✓	NCCMA
Oreoica gutturalis	Crested bellbird			Known	✓	NCCMA
Plegadis falcinellus	Glossy ibis		✓	Known		NCCMA
Pomatostomus temporalis temporalis	Grey-crowned babbler			Known	✓	NCCMA
Stagonopleura guttata	Diamond firetail			Known	✓	NCCMA
Tringa nebularia	Common greenshank		✓	Known		NCCMA
Ardea modesta	Eastern great egret		✓	Known		NCCMA DSE
Oxyura australis	Blue-billed duck			Known	✓	NCCMA DSE

Species	Common name	EPBC status	Migratory (EPBC)	Presence	FFG listing*	Source**
Stictonetta naevosa	Freckled duck			Known	✓	NCCMA DSE
Haliaeetus leucogaster	White-bellied sea-eagle		✓	Known	✓	NCCMA DSE EPBC
Lathamus discolor	Swift Parrot	E		Known	✓	NCCMA EPBC
Merops ornatus	Rainbow bee-eater		✓	Known		NCCMA EPBC
Mammal						
Nyctophilus timoriensis (South-eastern form)	Greater long-eared bat	V		May	✓	EPBC

V Vulnerable
E Endangered
CE Critically endangered
* FFG Listing under the provisions of Part 3 of the *Flora and Fauna Guarantee Act 1988*
** Source EPBC: EPBC Act, Protected Matters Search Tool website (accessed 18 July 2011)
DSE: Department of Sustainability and Environment, Biodiversity Interactive Map website (accessed 18 July 2011).
NCCMA: NCCMA (2010). Lake Leaghur Environmental Watering Plan. Prepared for the Northern Victoria Irrigation Renewal Project, North Central Catchment Management Authority, Huntly, Victoria.

Lake Meran

Lake Meran threatened species list

Species	Common name	EPBC status	Migratory (EPBC)	Presence	FFG listing*	Source **
Flora						
Lepidium monoplocoides	Winged pepper-cress	E		Likely	✓	EPBC
Maireana cheelii	Chariot wheels	V		Likely		EPBC
Swainsona murrayana	Slender darling-pea	V		Likely	✓	EPBC
Swainsona swainsonioides	Downy swainson-pea			Known	✓	NCCMA
Fish						
Bidyanus bidyanus	Silver perch			Known	✓	NCCMA, DSE
Craterocephalus fluviatilis	Murray hardyhead	V		May	✓	EPBC
Maccullochella peelii peelii	Murray cod	V		May	✓	NCCMA, EPBC, DSE
Macquaria australasica	Macquarie Perch	E		May	✓	EPBC
Amphibians						
Litoria raniformis	Growling Grass Frog, Southern	V		Likely	✓	EPBC

Species	Common name	EPBC status	Migratory (EPBC)	Presence	FFG listing*	Source **
Reptile						
Delma impar	Striped legless lizard	V		May	✓	EPBC
Birds						
Acrocephalus stentoreus	Clamorous reed warbler		✓	Known		NCCMA
Apus pacificus	Fork-tailed swift		✓	May		EPBC
Ardea alba	Great egret, white egret		✓	May		EPBC
Ardea ibis	Cattle egret		✓	May		EPBC
Ardea modesta	Eastern great egret		✓	Known		NCCMA, DSE
Gallinago hardwickii	Latham's snipe, Japanese snipe		✓	Known		EPBC
Haliaeetus leucogaster	White-bellied sea-eagle		✓	Likely	✓	EPBC
Hirundapus caudacutus	White-throated needletail		✓	May		EPBC
Lathamus discolor	Swift Parrot	E		Known	✓	EPBC
Merops ornatus	Rainbow bee-eater		✓	Known		NCCMA, EPBC
Pedionomus torquatus	Plains-wanderer	V		Likely	✓	EPBC
Pomatostomus temporalis temporalis	Grey-crowned babbler			Known	✓	NCCMA
Rostratula australis	Australian painted snipe	V		May	✓	NCCMA
Rostratula benghalensis s. lat.	Painted snipe		✓	May		EPBC
Stagonopleura guttata	Diamond firetail			Known	✓	NCCMA, DSE
Sterna caspia	Caspian tern		✓	Known	✓	NCCMA, DSE
Xanthomyza phrygia	Regent honeyeater	E	✓	May	✓	EPBC
Mammals						
Nyctophilus timoriensis (South-eastern form)	Greater long-eared bat	V		May	✓	EPBC

V Vulnerable
E Endangered
CE Critically endangered
* FFG Listing under the provisions of Part 3 of the *Flora and Fauna Guarantee Act 1988*
** Source EPBC: EPBC Act, Protected Matters Search Tool website (accessed 18 July 2011)
DSE: Department of Sustainability and Environment, Biodiversity Interactive Map website (accessed 18 July 2011)
NCCMA: NCCMA (2010). Lake Meran Environmental Watering Plan. Prepared for the Northern Victoria Irrigation Renewal Project, North Central Catchment Management Authority, Huntly, Victoria.

Lake Yando

Lake Yando threatened species list

Species name	Common name	EPBC status	Migratory (EPBC)	Presence	FFG listing*	Source**
Flora						
Amphibromus fluitans	River swamp wallaby-grass	V		May		EPBC
Lepidium monoplocoides	Winged pepper-cress	E		Likely	✓	EPBC
Maireana cheelii	Chariot wheels	V		Likely		EPBC
Pimelea spinescens subsp. spinescens	Plains rice-flower	CE		May	✓	EPBC
Swainsona murrayana	Slender darling-pea	V		Likely	✓	EPBC
Fish						
Craterocephalus fluviatilis	Murray hardyhead	V		may	✓	NCCMA DSE EPBC
Maccullochella peelii peelii	Murray cod	V		May	✓	EPBC
Macquaria australasica	Macquarie Perch	E		May	✓	EPBC
Tandandus tandanus	Freshwater catfish			Known	✓	NCCMA
Amphibians						
Litoria raniformis	Growling Grass Frog, Southern	V		Likely	✓	EPBC
Reptiles						
Delma impar	Striped legless lizard	V		May	✓	NCCMA epbc
Birds						
Apus pacificus	Fork-tailed swift		P	May		EPBC
Ardea alba	Great egret, white egret		P	May		EPBC
Ardea ibis	Cattle egret		P	May		EPBC
Ardea modesta	Eastern great egret		P	Known		DSE
Egretta garzetta	Little egret			Known	✓	NCCMA
Gallinago hardwickii	Latham's snipe, Japanese snipe		P	Known		EPBC
Haliaeetus leucogaster	White-bellied sea-eagle		P	Likely	✓	NCCMA epbc
Hirundapus caudacutus	White-throated needletail		P	May		EPBC

Species name	Common name	EPBC status	Migratory (EPBC)	Presence	FFG listing*	Source**
Lathamus discolor	Swift Parrot	E		Likely	✓	EPBC
Leipoa ocellata	Malleefowl	V		Likely	✓	EPBC
Merops ornatus	Rainbow bee-eater		P	Known		NCCMA EPBC
Oxyura australis	Blue-billed duck			Known	✓	NCCMA
Pedionomus torquatus	Plains-wanderer	V		Likely	✓	EPBC
Plegadis falcinellus	Glossy ibis		P	Known		NCCMA
Polytelis swainsonii	Superb parrot	V		May	✓	EPBC
Pomatostomus temporalis temporalis	Grey-crowned babbler			Known	✓	NCCMA DSE
Rostratula australis	Australian painted snipe	V		May	✓	EPBC
Rostratula benghalensis s. lat.	Painted snipe		P	May		EPBC
Stictonetta naevosa	Freckled duck			Known	✓	NCCMA
Tringa nebularia	Common greenshank		P	Known		NCCMA
Xanthomyza phrygia	Regent honeyeater	E	P	May	✓	EPBC
Mammals						
Nyctophilus timoriensis (South-eastern form)	Greater long-eared bat	V		May	✓	EPBC

V Vulnerable
E Endangered
CE Critically endangered
* FFG Listing under the provisions of Part 3 of the *Flora and Fauna Guarantee Act 1988*
** Source EPBC: EPBC Act, Protected Matters Search Tool website.
DSE: Department of Sustainability and Environment, Biodiversity Interactive Map website.
NCCMA: NCCMA (2010). Lake Yando Environmental Watering Plan. Prepared for the Northern Victoria Irrigation Renewal Project, North Central Catchment Management Authority, Huntly, Victoria.

Appendix 6: Risk assessment framework

Risk likelihood rating

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

Risk consequence rating

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

Risk analysis matrix

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

Australian Government

Commonwealth Environmental Water

ENVIRONMENTAL WATER DELIVERY

Lower Broken Creek

AUGUST 2011 V1.0

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Barmah Island and Broken Creek
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Peter Cottingham & Associates and SKM (2011). *Environmental Water Delivery: Lower Broken Creek.* Prepared for Commonwealth Environmental Water, Department of Sustainability, Environment, Water, Population and Communities, Canberra.

ISBN: 978-1-921733-25-3

SEWPaC acknowledges the following individuals and organizations that have been consulted in the preparation of this document:

Michael Jensz (Department of Sustainability and Environment, Victoria)
Andrew Shields (Goulburn-Murray Water)
Mark Bailey (Goulburn-Murray Water)
Geoff Earl (Goulburn Broken Catchment Management Authority)
Garry Smith (DG Consulting)
Ben Gawne (Murray-Darling Freshwater Research Centre)
Daren Barma (Barma Water Resources)
Murray-Darling Basin Authority

Published by the Commonwealth Environmental Water Holder for the Australian Government.

ENVIRONMENTAL WATER DELIVERY

Lower Broken Creek

AUGUST 2011 V1.0

Environmental Water Delivery: Lower Broken Creek

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 Lower Broken Creek system.

The Lower Broken Creek supports significant biodiversity by providing valuable habitat in a highly modified landscape. Biodiversity values associated with Lower Broken Creek include the presence of regionally significant native fish populations and areas of intact riparian vegetation. Potential water use options for the Lower Broken Creek include the provision of water to augment baseflows at Reach 3 to maintain or expand native fish populations through the creek and to support water quality.

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, Goulburn-Murray Water, Goulburn Broken 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.

Commonwealth Environmental Water
Department of Sustainability, Environment, Water, Population and Communities
GPO Box 787, Canberra ACT 2601
Tel: +61 2 6275 9245

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Acronyms

ACRONYM	MEANING
BACI	Before-after-control-impact
BE	Bulk Entitlement
CEWH	Commonwealth Environmental Water Holder
COAG	Council of Australian Governments
DO	Dissolved Oxygen
DPI	Victorian Department of Primary Industries
DSE	Victorian Department of Sustainability and Environment
EVC	Ecological vegetation classes
eWater CRC	eWater Co-operative Research Centre
GBCL	Goulburn-Broken-Campaspe-Loddon
GB CMA	Goulburn Broken Catchment Management Authority
GMID	Goulburn-Murray Irrigation District
G-MW	Goulburn-Murray Water
ISC	In stream condition
IVTs	Inter-valley transfers
MDBA	Murray-Darling Basin Authority
NERWMP	North East Regional Water Monitoring Partnership
NRSWS	The Northern Region Sustainable Water Strategy
NVIRP	Northern Victoria Irrigation Renewal Project
SEWPAC	Department of Sustainability, Environment, Water, Population and Communities
SRA	Sustainable Rivers Audit
TLM	The Living Murray
Tungamah D&S scheme	Tungamah domestic and stock scheme
VEFMAP	Victorian Environmental Flows Monitoring and Assessment Program
VEWH	Victorian Environmental Water Holder
VRHS	Victorian River Health Strategy
VWQMN	Victorian Water Quality Monitoring Network

PART 1
Management aims

1. Overview

1.1 Scope and purpose of this document

Information provided 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 the application of large volumes of environmental water.

To maximise the system's benefit, three scales of watering objectives have been 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.

Information provided focuses on the environmental watering objectives and water use strategy for the Lower Broken Creek in northern Victoria. This includes options for the use of water held in the Goulburn and Murray system storages.

As part of this project, assets and potential watering options have been 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 options have been developed for each asset to meet watering objectives under a range of volume 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 options will provide an "event ready" basis for the allocation of environmental water in the 2011 autumn and spring seasons. These options will be integrated into a five-year water delivery program.
3. Processes and mechanisms required to operationalise environmental water delivery have been documented and include:
   - delivery arrangements and operating procedures
   - water delivery accounting methods (in consultation with operating authorities) 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.

1.2 Catchment and river system overview

The catchment area of Broken Creek covers approximately 3,300 square kilometres of the Murray Valley Riverine Plains (SKM 1998), encompassing the western slopes of the Warby Ranges and northern slopes of the foothills around Dookie. The creek lies within the Victorian Riverina and Murray Fans Bioregions. Much of the catchment is cleared for dryland and irrigated agriculture.

Prior to the development of irrigation infrastructure, Broken Creek was an ephemeral system with flows predominantly occurring in winter and early spring. Historically, Broken Creek would have received inflows from the Broken River upstream of the present location of Casey's Weir in approximately one year in five (Reich et al. 2009). However, the regulation of the system for irrigation, stock and domestic supply has significantly modified the hydrologic regime in Broken Creek, turning the system into a largely perennial system dominated by summer flows and permanent weir pools.

The terms Upper Broken Creek and Lower Broken Creek are often used to refer to reaches of the creek upstream and downstream of the Boosey Creek confluence respectively (Water Technology 2010). For the purposes of this report, the Lower Broken Creek is defined as a small section of the Boosey Creek downstream of the Murray Valley 7/3 channel outfall, the Lower Broken Creek and Nine Mile Creek. The Murray Valley Irrigation Area is north of the creeks, while the Shepparton Irrigation Area is to the south.

The Lower Broken Creek and Nine Mile Creek have been regulated for more than 50 years. Under natural conditions, the creeks would have ceased to flow during summer and autumn. Today the creeks are perennial streams with significant flows maintained through summer and autumn to supply water for irrigation, stock and domestic, and urban use. There are a number of weirs downstream of Katamatite that maintain water levels for private pumps. Water quality in the weir pools during summer and autumn is often poor, and in recent years environmental managers have passed increasing volumes of water down the creek to manage threats posed by low dissolved oxygen levels and blooms of the water fern Azolla.

The major sources of regulated inflows to the Lower Broken Creek are discharges from the Shepparton and Murray Valley Irrigation Area channel systems, including from the East Goulburn Main Channel and the Murray Valley 7/3 channel (Figure 1). The major sources of unregulated inflows are the upstream catchments (i.e. the Upper Broken Creek and Boosey Creek), Shepparton Drain 11, Shepparton Drain 12 and Murray Valley Drain 13. In the drought years from 1997 to 2009, unregulated inflows were a very small proportion of total inflows. Altogether, there are currently eleven outfall structures and six drains that connect directly to the Lower Broken Creek from the Murray Valley Irrigation Area, while five outfall structures and six drains connect directly to the Lower Broken Creek and Nine Mile Creek from the Shepparton Irrigation Area. As part of the Northern Victoria Irrigation Renewal Project (NVIRP), seven of the eleven Murray Valley outfall structures connected to the creek will be decommissioned (Water Technology 2010). The outfall structures that will be retained are denoted by an asterisk in Figure 1. Some outfall structures discharging to drains will also be removed.

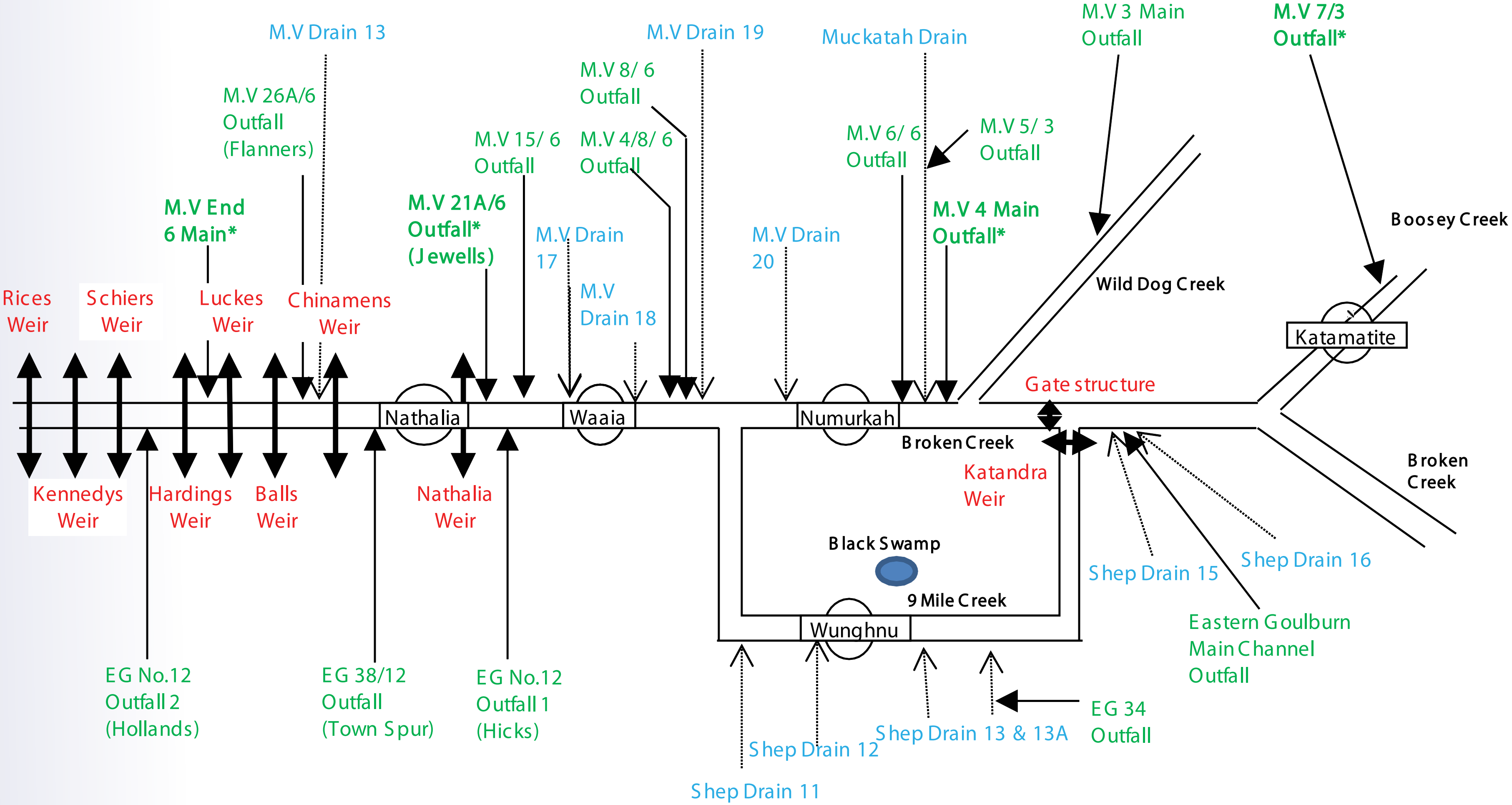

Figure 1: A schematic of the Lower Broken Creek and Nine Mile Creek system (SKM 2003).

The names of regulating structures are in red, the names of drains are in blue and the names of outfalls are in green. Murray Valley outfall structures that will not be removed as part of the NVIRP works are shown by an asterisk. All outfall structures on the Shepparton side of the creeks are being retained (Water Technology 2010).

1.3 Overview of river operating environment

Regulation of flows along the Lower Broken Creek is managed by Goulburn-Murray Water (G-MW). Under the Bulk Entitlement (BE) framework, the Lower Broken Creek (including Nine Mile Creek) is managed as one system, although it is part of both the Murray River and Eildon-Goulburn Weir BEs. About 40,000 ML of regulated water is needed in a normal year to supply the consumptive demands along the Lower Broken Creek system, and to cover transmission and operational losses. This water normally comes from the Goulburn system via the East Goulburn Main Channel (Schedule 3 of the Eildon-Goulburn Weir BE).

Although the majority of water supplied to the Lower Broken Creek is from the Goulburn system, the entitlements of most consumptive users are specified in the Murray River BE. The seasonal allocations that apply are those announced for Victorian water shares in the Murray River system. The remainder of entitlements have Goulburn system allocations.

In low allocation years, the supply of water from the Goulburn system to the Lower Broken Creek is reduced, and the shortfall in supply is met by the Murray system. The contribution from the Goulburn system in gigalitres is generally based on the formula: 5 + 35 x Goulburn allocation (A. Shields, G-MW, pers. comm., 2010). All Murray Valley irrigators pay slightly different water storage and supply charges from the normal Murray River charges, reflecting the fact that some of their water (though only used in the Broken Creek part) comes from the Goulburn system.

Environmental water management, including the Goulburn Water Quality Reserve (30,000 ML), is planned by the Goulburn Broken Catchment Management Authority (GB CMA), in cooperation with G-MW, the Victorian Department of Sustainability and Environment (DSE) and Murray-Darling Basin Authority. Lower Broken Creek is managed as three main reaches (Figure 2):

- Reach 1: Broken Creek from Boosey Creek to Nine-Mile Creek.
- Reach 2: Broken Creek from Nine-Mile Creek to Nathalia.
- Reach 3: Broken Creek from Nathalia to the Murray River.

Nine Mile Creek is excluded from this document, as it is not operated during winter and, as a highly modified channel, has less of the fish habitat that is highly valued in the Lower Broken Creek. The main objectives of environmental water delivered to the Lower Broken Creek relate to the prevention or mitigation of poor water quality that can occur following excessive growth of the water fern Azolla and maintaining habitat and passage for native fish. Environmental releases are generally made to meet the ecosystem needs of Reach 3 in spring and over summer to autumn, when water is delivered to meet irrigation demand along the other reaches. Other assets near Lower Broken Creek, such as Black Swamp and Purdies Swamp, currently receive water in most years. The volume required to fill these wetlands is relatively small (e.g. 100 ML); for these reasons they are not considered in the current version of this document.

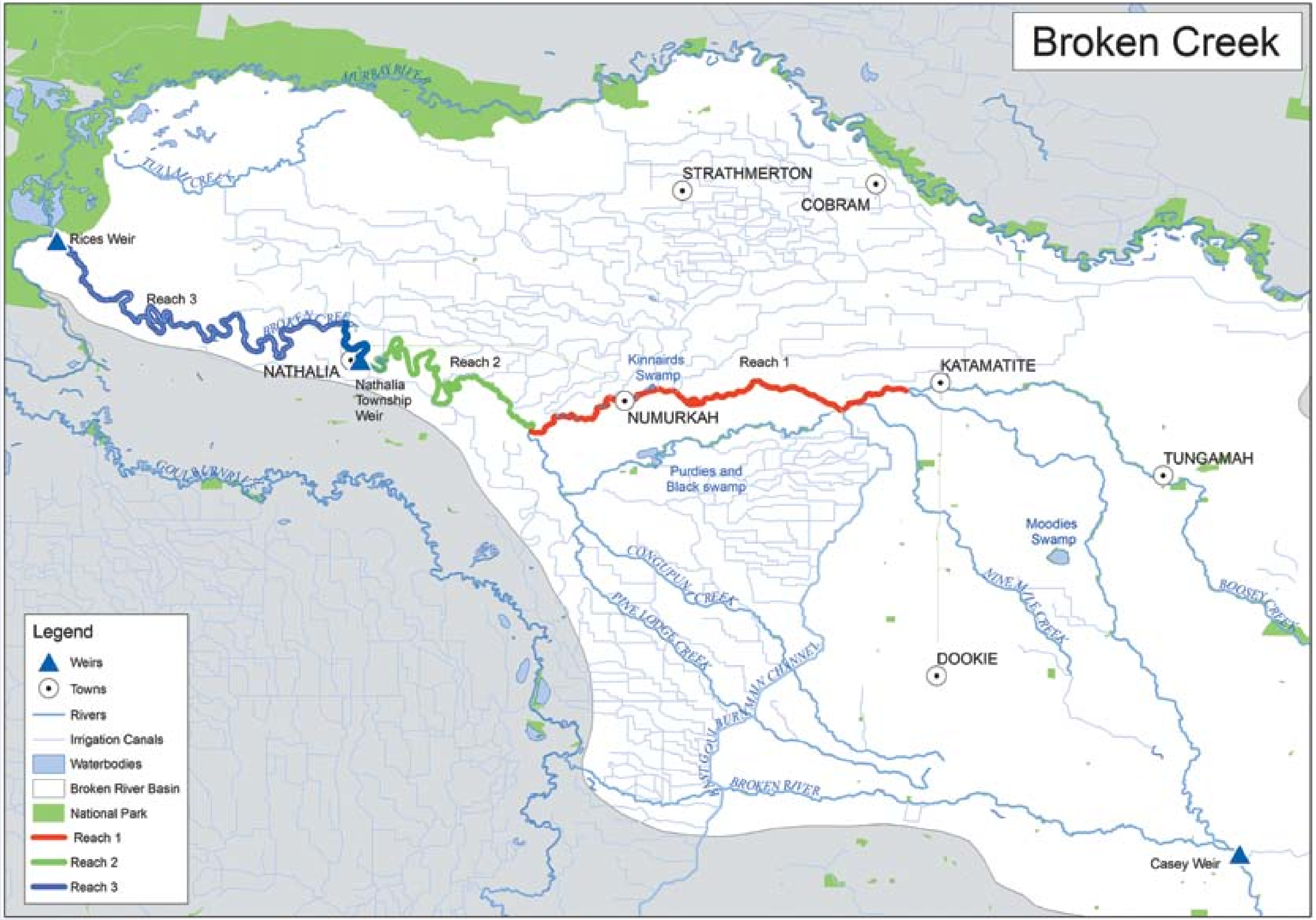

Figure 2: Reaches along Lower Broken Creek (SEWPaC 2011).

2. Ecological values, processes and objectives

2.1 Summary of ecosystem values

Ecosystem values associated with the Lower Broken Creek include the presence of (Water Technology 2010, URS 2005):

- 20 ecological vegetation classes (EVC, see Appendix 1), including the following threatened and/or regionally significant examples:
  - EVC68 – Creekline Grassy Woodland
  - EVC168 – Drainage Line Aggregate
  - EVC259 – Plains Grassy Woodland / Gilgai Wetland Mosaic
  - EVC803 – Plains Woodland.
- Numerous riparian plant species of conservation significance
- Threatened and regionally significant native fish species, including:
  - Murray cod (*Maccullochella peelii peelii*)
  - Silver perch *(Bidyanus bidyanus)*
  - Golden perch *(Macquaria ambigua)*
  - Unspecked hardyhead *(Craterocephalus stercusmuscarum fulvus)*
  - Crimson-spotted rainbow fish (*Melanotaenia fluviatilis*).

The native fish populations of Lower Broken Creek, particularly Murray cod, are considered to be of regional significance (GB CMA 2005). While a result of water resource development and regulation, the presence of weir pools along the Lower Broken Creek has provided additional habitat for deep-bodied native fish that might not otherwise exist.

Overall, the Lower Broken Creek supports important plant and animal habitat and biodiversity in a region whose landscape has been greatly modified. It also complements the habitat and biodiversity values associated with nearby systems such as the Lower Goulburn River and the Murray River.

2.2 Broad-scale ecosystem objectives

2.2.1 Murray-Darling Basin

The following ecosystem-scale objectives, proposed by the MDBA (2010), are relevant when considering options for the use of environmental water in the Lower Broken Creek:

- Maintain and improve the ecological health of the Basin, and in doing so optimise the social, cultural, and economic well-being of Basin communities.
- Improve the resilience of key environmental assets, water-dependent ecosystems and biodiversity in the face of threats and risks that may arise in a changing environment.
- Maintain appropriate water quality, including salinity levels, for environmental, social, cultural and economic activity in the Basin.

These and flow-related ecological objectives that are the basis for management plans for Lower Broken Creek (Water Technology 2010, GB CMA 2005, GB CMA 2008, URS 2005) are important considerations when allocating environmental water to the Lower Broken Creek.

2.2.2 Goulburn Broken catchment

The Goulburn Broken Regional River Health Strategy (GB CMA 2005) aims to achieve four main objectives:

1. Enhance and protect the rivers that are of highest community value from any decline in condition.
2. Maintain the condition of ecologically healthy rivers (as defined in the Victorian River Health Strategy).
3. Achieve an 'overall improvement' in the environmental condition of the remainder of rivers.
4. Prevent damage from inappropriate development and activities.

3. Watering objectives

3.1 Proposed asset watering objectives

The following environmental watering objectives were identified for the Lower Broken Creek in developing Interim Environmental Flows Recommendations (GB CMA 2008) and are used when considering various existing management plans and the impact of the Northern Victoria Irrigation Renewal Project (Water Technology 2010):

- Native Fish – Improve native fish habitat and passage. Ensure persistence of aquatic habitats during migration and breeding seasons, particularly for Murray cod. Supply sufficient flow to operate the fishways and provide fish access to appropriate habitat all year.
- Wetlands – Restore a more natural flood regime to Black and Purdies Swamps.
- Low Dissolved Oxygen – Maintain dissolved oxygen concentrations above 5 mg/L (based on ANZECC guidelines to maintain suitable conditions for oxygen dependent species).
- Algal and Azolla blooms – Minimise the growth of Azolla and algae.

In effect, the objectives listed above serve as risk mitigation measures to protect or improve the environmental values associated with the Lower Broken Creek.

The objective for wetlands requires a return to a more natural pattern of wetting and drying. Until recently, wetlands such as Black Swamp and Purdies Swamp have a history of being water-logged due to their connection to Nine Mile Creek. Their management requires less frequent inundation from Nine Mile Creek, rather than additional water.

Potential watering options to achieve objectives related to native fish and their habitat, low DO and Azolla are presented in Table 1 and summarised in Table 2. Given that water levels are maintained at high levels due to the influence of weirs and their operation, no objectives have been set for floodplain vegetation, as this would risk the high-value black box communities present along the creek (Water Technology 2010).

Table 1: Proposed flow objectives for reaches along the Lower Broken Creek (Water Technology 2010).

Flow Target	Daily Flow ML/d											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
Reach 1												
Native Fish Passage	40	40	40	40	40			40	40	40	40	40
Reach 3												
Native Fish Habitat									250	250	250	
Native Fish Passage	40	40	40	40	40			40	40	40	40	40
Collective Requirement	40	40	40	40	40			40	250	250	250	40
Reach 4												
Azolla & Dissolved Oxygen (DO)	250	250	250	250						250	250	250
Provisional DO and Azolla flows*	100	100	100	100						100	100	100
Native Fish Habitat									250	250	250	
Native Fish Passage	40	40	40	40	40			40	40	40	40	40
Collective Requirement^	350	350	350	350	40			40	250	350	350	350

* Additional flows up to 200 ML/d may be required depending on seasonal conditions.
^ Volumes for native fish passage are not included in the Collective Requirement figures as flows for Azolla and DO will provide the target flows for this objective.

Management is driven by objectives for Reach 3: Nathalia weir pool to the Murray River (highest ecosystem values), given low flows once irrigation demand has been met. Objectives will likely remain relatively constant, irrespective of climatic conditions, as DO and Azolla issues can arise in most years (although Azolla issues are less likely in median and wet years). The recommended flows for January–March are usually met with existing water entitlements and inter-valley transfers.

Table 2: Summary of water use objectives for the Lower Broken Creek.

	Management objectives for specific water availability scenarios			
	Extreme dry	**Dry**	**Median**	**Wet**
	Goal: Avoid damage to key ecological assets	Goal: Ensure ecological capacity for recovery	Goal: Maintain ecological health and resilience	Goal: Improve and extend healthy aquatic ecosystems
Water availability	Minimum allocation on record	30th percentile year	50th percentile year	70th percentile year
Broken Creek				
Reach 3 objectives	• Maintain water quality to prevent deaths of Murray cod and other native fish populations throughout the year • Maintain a reduced native fish population distribution in the creek	• Maintain water quality to prevent deaths of Murray cod and other native fish populations throughout the year • Maintain a reduced native fish population distribution in the creek	• Maintain water quality to prevent deaths of Murray cod and other native fish populations throughout the year • Maintain or expand native fish population distributions in the creek	• Maintain water quality to prevent deaths of Murray cod and other native fish populations throughout the year • Maintain or expand native fish populations distribution in the creek
Potential use of environmental water	Environmental water could be used to supplement baseflows in the non-IVT season (April–May and August–December): • Baseflow of up to 40 ML/d is required in April–May to maintain fish passage • Baseflow of up to 80–200ML/d is required in August to manage Azolla, as well as provide fish passage • Baseflow of up to 250 ML/d is required from September to December to maintain fish passage, manage Azolla and DO, as well as provide fish habitat.	Environmental water could be used to supplement baseflows in the non-IVT season (April–May and August–December): • Baseflow of up to 40 ML/d are required in April–May to maintain fish passage • Baseflow of up to 80–200ML/d is required in August to manage Azolla, as well as provide fish passage • Baseflow of up to 250 ML/d is required from September to December to maintain fish passage, manage Azolla and DO, as well as provide fish habitat.	Environmental water could be used to supplement baseflows in the non-IVT season (April–May and August–December): • Baseflow of up to 40 ML/d are required in April–May to maintain fish passage • Baseflow of up to 80–200ML/d is required in August to manage Azolla, as well as provide fish passage • Baseflow of up to 250 ML/d is required from September–December to maintain fish passage, manage Azolla and DO, as well as provide fish habitat. • Catchment runoff makes the need for water to manage Azolla less likely in median years.	Environmental water could be used to supplement baseflows in the non-IVT season (April–May and August–December): • Baseflow of up to 40 ML/d are required in April–May to maintain fish passage • Baseflow of up to 80–200ML/d is required in August to manage Azolla, as well as provide fish passage • Baseflow of up to 250 ML/d is required from September–December to maintain fish passage, manage Azolla and DO, as well as provide fish habitat. • Catchment runoff makes the need for water to manage Azolla less likely in wet years.

PART 2:
Water use strategy

4. Environmental water requirements

4.1 Baseline flow characteristics

Of total inflows to the Lower Broken Creek and Nine Mile Creek systems, the majority comes through the channel outfall structures (Figure 3). Drought conditions during the 10 years to 2008–09 have reduced the percentage contributions from unregulated sources of water (i.e. the upstream catchments and drains), while the percentage contribution from outfall structures has increased. In 2008–09, inflows from outfall structures contributed approximately 95 per cent of total inflows. At the same time as the percentage contribution to inflows from outfall structures increased, the inflows through outfall structures in excess of orders decreased. In short, the distribution of water through outfall structures to the Lower Broken Creek and Nine Mile Creek has been managed more tightly in recent years (Figure 4).

Interestingly, over the five years to 2008–09, the volume of water ordered through outfall structures by environmental managers (using environmental allocations or inter valley transfers (IVTs)) rapidly increased, while the volumes ordered by diverters decreased (Figure 5). In 2008–09, the volume of water ordered for the environment and IVTs exceeded local diverter orders for the first time. The decrease in diverter orders can be linked with Victorian Murray and Goulburn irrigation allocations (Table 3). As allocations decreased, the volume of water ordered by diverters also decreased. Environmental managers have, therefore, needed to order more water for the Lower Broken Creek system for the purpose of maintaining sufficient water quality in the weir pools.

Inflows to the Lower Broken Creek and Nine Mile Creek systems through drains have also declined significantly over the 10 years to 2008–09. In the late 1990s and early 2000s, drainage inflows to the system were 30–35,000 ML/year. In the mid to late 2000s however, inflows from drains have been a minor component of total inflows. This reduction in drainage inflows is probably attributable to a combination of less rainfall runoff, less runoff from irrigation application, less channel outfalls into drainage systems, increased drainage diversions and a focus on reducing drainage flows.

The contribution of total inflows is weighted to the upstream end of the Lower Broken Creek. This is particularly the case in recent years (eg. 2008–09), when minimal inflows to the system were recorded downstream of where the Lower Broken Creek and Nine Mile Creek split. Of the total inflows to the Lower Broken Creek system, a large portion flows downstream and passes to the Murray River (Figure 6). Over the 10 years to the end of 2008–09, the annual flow past Rice's Weir has only been 25 to 45 per cent lower than total estimated inflows.

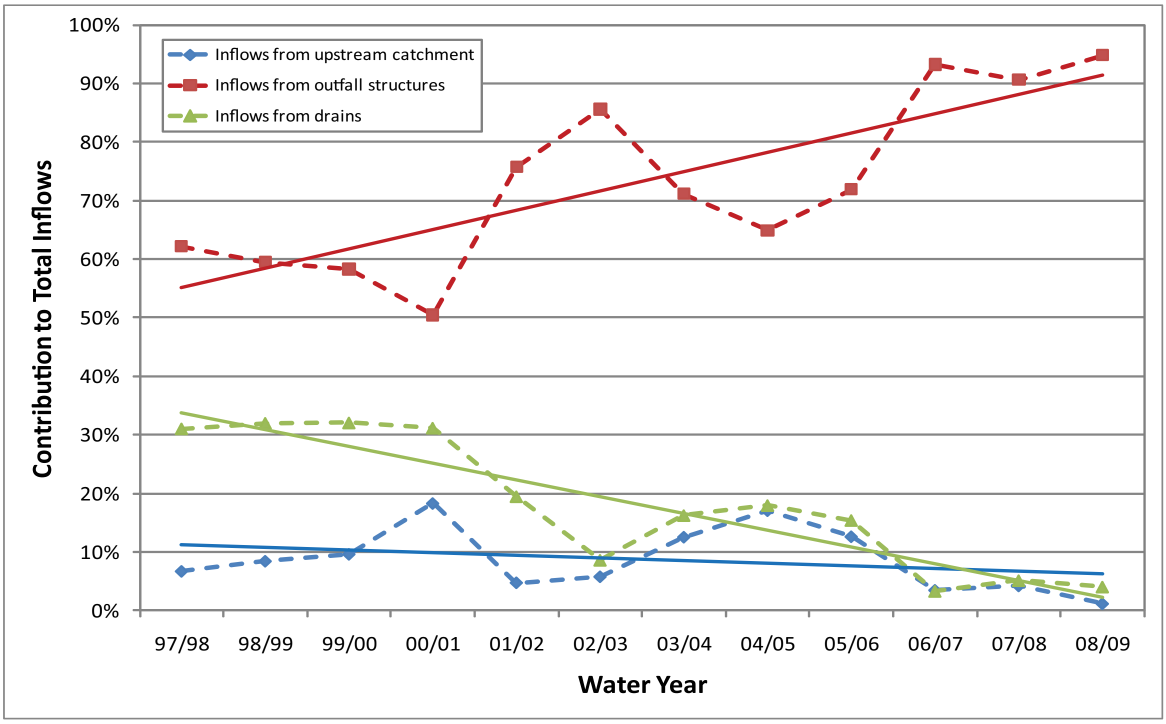

Figure 3: The contribution of inflows from the upstream catchment, outfall structures and drains (SKM 2010).

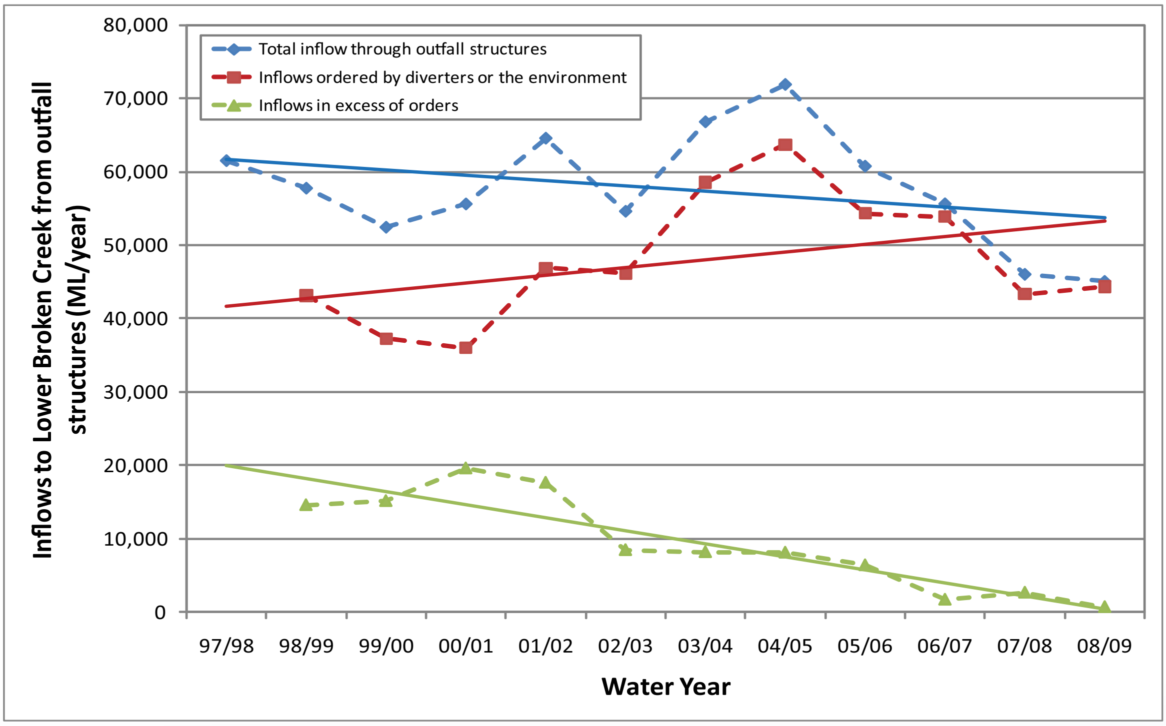

Figure 4: The total inflow through outfall structures, divided into ordered inflows and inflows in excess of orders (SKM 2010).

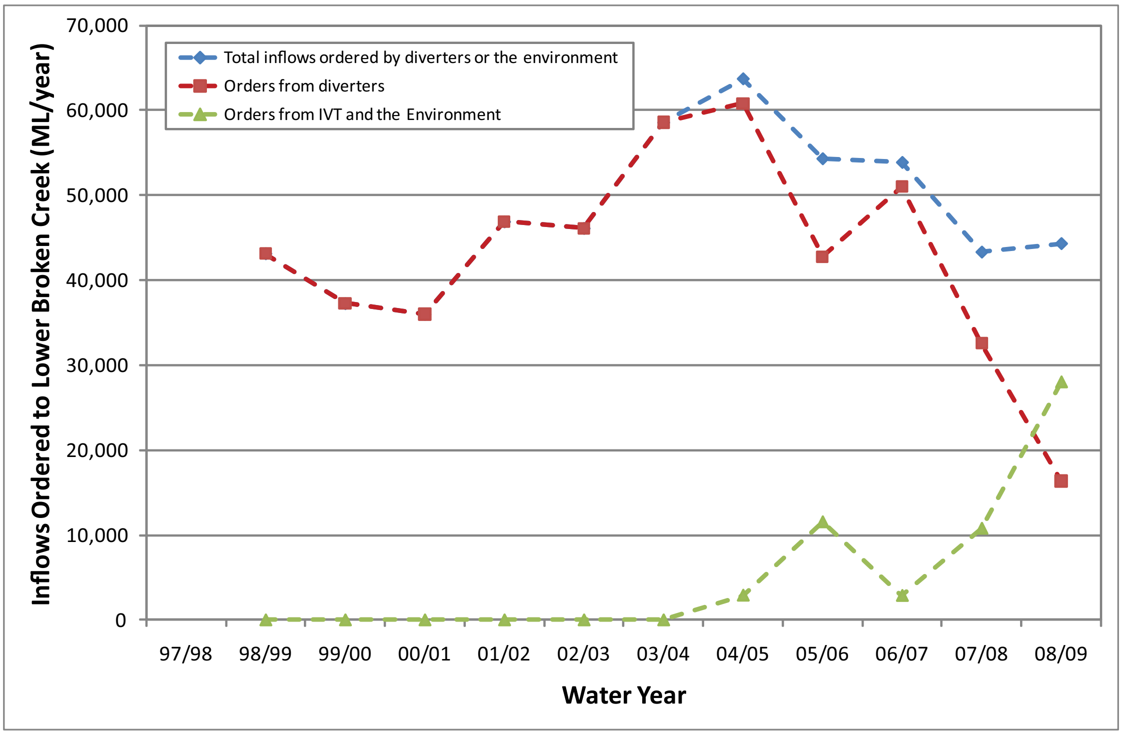

Figure 5: The volume of ordered water for diverters, the environment and inter-valley transfers (SKM 2010).

Table 3: Victorian Murray and Goulburn February irrigation allocations.

Water Year (July–June)	Murray Allocation*	Goulburn Allocation*
1996–97	200%	200%
1997–98	130%	120%
1998–99	200%	100%
1999–00	130%	100%
2000–01	200%	100%
2001–02	200%	100%
2002–03	129%	53%
2003–04	100%	100%
2004–05	100%	100%
2005–06	141%	100%
2006–07	95%	25%
2007–08	42%	53%
2008–09	35%	33%
2009–10	100%	71%

* Note, final allocations did increase after February in 2005–06 and 2007–08 on the Victorian Murray system and 2002–03, 2006–07 and 2007–08 on the Goulburn system.

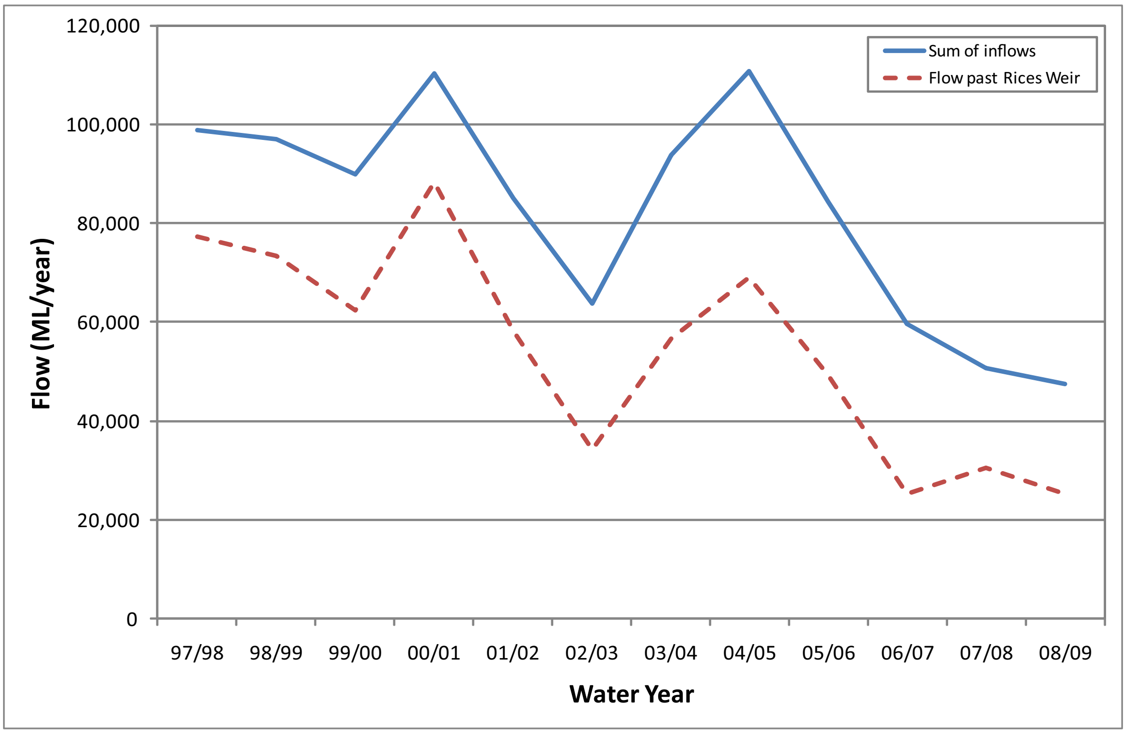

Figure 6: A comparison of annual total inflows (including from the upstream catchments, outfalls and drains) and annual flow past Rice's Weir.

A long term computer model of the Lower Broken Creek has not yet been developed. An existing daily FORTRAN model only covers the period 1 January 1997 to 30 June 2002. The MDBA developed a regression model of Broken Creek flows at Rice's Weir (only) by fitting to gauged flow data from 1965 to 1994 (MDBC 2003). The regression relates flow in the creek to climate variables and a time trend over the period 1965 to 1994, which has been set as a constant at the year 1994 in the current MSM-Bigmod input. The regressions vary by season from 0.26 (poor) to 0.85 (good) and will not represent current (2010) irrigation system operation. Therefore gauged flow data has been used in the information presented below, with the regressed MDBA data at Rice's Weir provided for reference purposes. There is a high degree of uncertainty associated with the relevance of the historical gauged data due to the recent changes in irrigation system operation previously discussed in this section.

This data shows that flow in the Boosey Creek at Tungamah and the Broken Creek at Katamatite ceases for approximately 20 per cent of the time. In contrast, there is flow past Rice's Weir for all but a small portion of time (Figure 7).

Flows past Rice's Weir are elevated in summer and autumn by regulated releases and operational overflows through outfall structures located along the Lower Broken Creek (Figure 8). In winter and spring, the average recorded flow is of similar magnitude to the average flow recorded in summer and spring, but this is because there are significant periods of data missing during winter and spring for 16 of the 45 years of record. In contrast, the MDBA modelled time-series for Rice's Weir, while showing elevated flows in summer and autumn, has the highest average flows occurring in spring. Drought conditions in the 2000s have resulted with flow past Rice's Weir falling below 10 ML/d for extended periods during winter and spring. The flow regime for the Boosey Creek at Tungamah and the Broken Creek at Katamatite follows a more natural pattern, with low flows in summer and higher flows in winter and spring, including occasional flood events.

On average, flows to the Lower Broken Creek from the upstream catchments for the period of record available are 33 ML/d for December to May and 157 ML/d for June to November (Table 4), although it is noted that flow in the Lower Broken Creek is driven by peak flow events rather than more regular flow (indicated by the shape of the flow duration curve). The bulk of these inflows come from the Boosey Creek catchment. Average daily flows past Rice's Weir for December to May and June to November are 300–500 ML/d, depending on whether the recorded or modelled streamflows are analysed.

Note that the pipelining of the Tungamah domestic and stock scheme, which was completed in 2007, is likely to lead to reduced summer flows (particularly baseflows) in the Upper Broken Creek into the future.

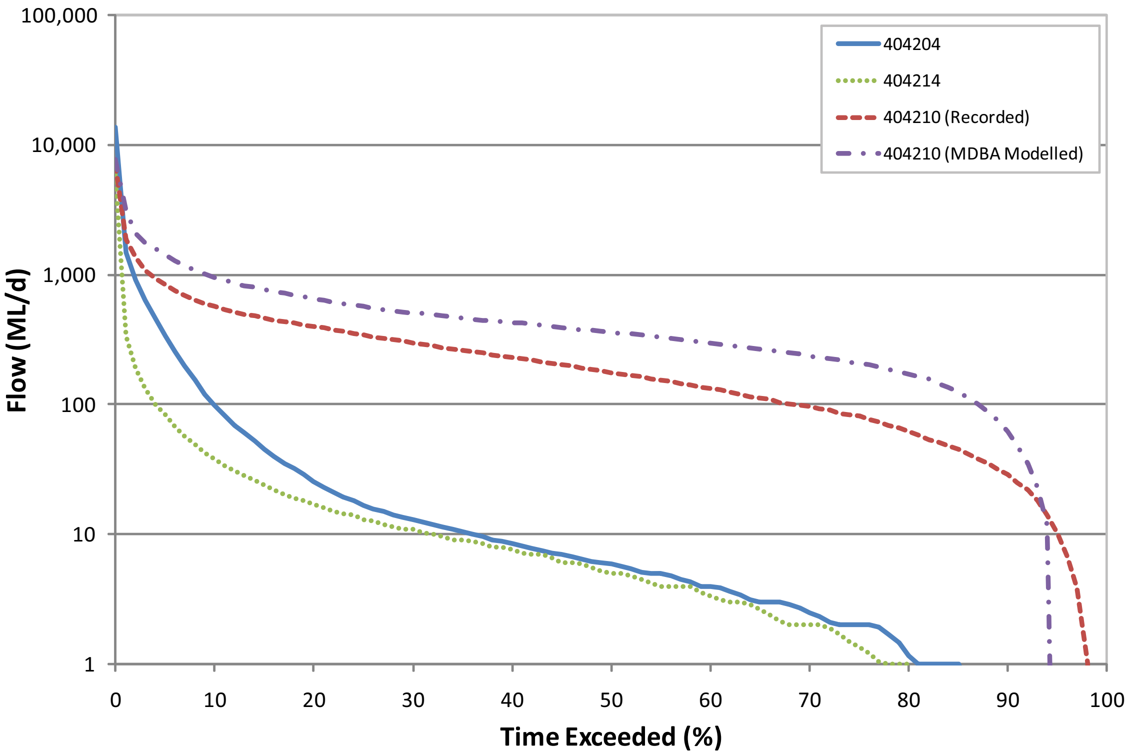

Figure 7: Daily flow duration curve for streamflow gauges at Tungamah (404204), Katamatite (404214) and Rice's Weir (404210).

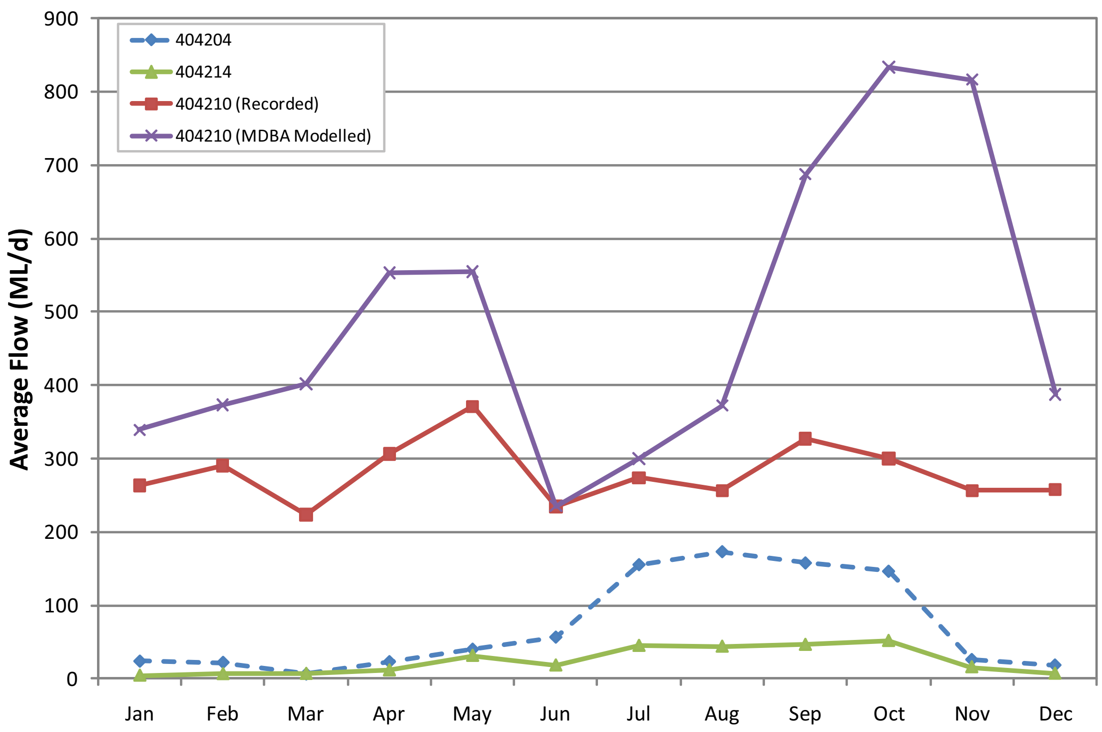

Figure 8: Average daily flow for streamflow gauges at Tungamah (404204), Katamatite (404214) and Rice's Weir (404210).

Table 4: Flow statistics for gauges at Tungamah (404204) and Katamatite (404214), and downstream gauge Rice's Weir (404210), based on the available periods of record.

Statistic (ML/d)	Flow Gauge				
	404204	404214	404204 + 404214	404210 (Recorded)^	404210 (Modelled)*
Minimum daily flow	0	0	0	0	0
Average daily flow	71	24	95	280	490
Maximum daily flow	13,700	5,910	15,800	7,050	7,670
Summer minimum daily flow	0	0	0	0	0
Summer average daily flow	22	11	33	286	435
Summer maximum daily flow	3,390	4,800	6,920	7,020	4,390
Winter minimum daily flow	0	0	0	0	0
Winter average daily flow	120	37	157	273	540
Winter maximum daily flow	13,700	5,910	15,800	7,050	7,670

Note: Summer refers to the months December to May, while Winter refers to the months June to November.
Note:^ Without infilling missing periods in the gauge record.
Note: *Modelled time-series was provided by the MDBA from BigMod for the period 1891–2009.

Table 5 shows that flow in the Lower Broken Creek (measured at Rice's Weir) is elevated in summer and autumn, and reduced in winter and spring. Although zero flows have been observed in nearly all months, these are typically short duration events. The longest periods of zero flow recorded have been 32 days in July–August 1979 and 23 days in August 2002. Note that the values in Table 5 are derived independently for each month. In the very dry year in particular, Table 5 highlights that zero flows can occur in each month of the year, but this does not necessarily mean that zero flows persist for the whole year.

Table 5: Streamflows (ML/d) for the Lower Broken Creek for recorded (1965–2009) and modelled (1895–2009) daily time-series.

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)	
	Record	Model	Record	Model	Record	Model	Record	Model
Jul	0	0	27	75	49	176	103	358
Aug	0	0	31	248	98	340	225	450
Sep	0	0	124	464	221	606	362	836
Oct	0	0	142	159	249	428	389	965
Nov	8	0	137	155	214	417	313	851
Dec	0	0	105	246	183	311	277	416
Jan	0	0	118	220	180	274	265	356
Feb	0	0	140	286	206	343	350	404
Mar	0	0	86	242	149	302	266	406
Apr	0	0	150	396	239	469	352	582
May	0	3	189	426	269	484	372	585
Jun	0	0	48	58	86	133	141	233

4.2 Environmental water demands

The aim for delivering water to the Lower Broken Creek is to provide baseflows of varying magnitudes at Rice's Weir to manage water quality and provide native fish habitat and passage (see Section 2).

Based on gauged data for the Lower Broken Creek at Rice's Weir, Table 6 shows the range of additional volumes required to meet the environmental flow recommendations in very dry, dry, median and wet years. The range of volumes required to meet environmental demand in dry to wet years ranged from 1,000 ML to 55,000 ML. The volume required in the two driest years on record was 42,000 – 47,000 ML. If Bigmod modeled flows are used for the baseline source data (run #20507), the volumes required are lower at around 24,000 – 25,000 ML for the very dry year and up to 36,000 ML for other years. The discrepancy between the modelled and gauged data is in part due to the different timeframes of the source data. With recent changes in system operation, volumes required could be higher (due to improved irrigation delivery system efficiency) or lower (due to IVT and environmental water deliveries by the Goulburn Broken CMA to manage water quality).

Table 6: Range of additional volumes required to achieve desired environmental flows in the Lower Broken Creek, based on modelled Victorian Murray allocations and flows at Rice's Weir.

Desired flow event	Baseline data source	Seasonal volume required to piggyback events	
		Very dry	Dry Median Wet
Baseflow	Modelled flows, 1895–2009	24 – 25 GL	0 – 36 GL
	Gauged data, 1976–2010	42 – 47 GL	1 – 55 GL

5. Operating regimes

5.1 Introduction

This section presents suggested operational triggers for implementation of the 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.
- Identifying any constraints on water delivery, such as available airspace in irrigation channels, 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 same flow requirements are recommended for all climate years (see Table 7).

5.3 Delivery triggers

Triggers for delivering flows to Broken Creek are listed in Table 7. The 40 ML/d baseflow should be provided throughout the nominated season, with environmental water allocations supplementing creek flows as required. G-MW would need to estimate the anticipated shortfall volume and manage deliveries to meet the target flow at Rice's Weir.

The delivery of the higher baseflows from August to December is driven by the need to manage water quality in the creek. Dissolved oxygen in Rice's Weir pool is continuously monitored by the GB CMA. When the dissolved oxygen drops below 5 mg/L the baseflows should be increased to improve water quality and reduce the risk of fish kills and algal blooms. In practice, because of the travel time along the creek through the irrigation system (discussed in the following section), environmental water managers should try and anticipate dissolved oxygen levels reaching this threshold approximately four days in advance by tracking trends in the recorded data. Delivery should cease when dissolved oxygen has increased above 5 mg/L, and the likelihood of it dropping below 5 mg/L with no additional deliveries is low. In practice this may involve throttling back deliveries over a period of days and closely monitoring dissolved oxygen levels.

The 30,000 ML Goulburn Water Quality Reserve has been used in recent years to manage water quality. This reserve is regarded as an emergency supply and may be drawn upon at a time of poor water quality.

Table 7: Summary of proposed operational regime for achievement of environmental objectives.

Climate year	Flow objective in Broken Creek (Reach 3)	Season/ timing	Average return period	Water quality trigger
All	40 ML/d baseflow at Rice's Weir.	Apr–May, Aug–Dec	All years.	Maintain throughout season with deliveries from Goulburn or Murray systems as required.
	80–200 ML/d baseflow at Rice's Weir.	Aug	All years.	Deliver when dissolved oxygen in Rice's Weir pool is expected to drop below 5 mg/L within four days.
	250 ML/d baseflow at Rice's Weir.	Sep–Dec	All years.	Deliver when dissolved oxygen in Rice's Weir pool is expected to drop below 5 mg/L within four days.

5.4 Travel time

Travel time along the Goulburn River between Lake Eildon and Goulburn Weir (the offtake point for the East Goulburn Main Channel) is assumed to be three days in the GBCL daily river system model. G-MW operations work on the basis of two days travel time during the irrigation season. Travel time along the Murray River between Lake Hume and Yarrawonga Weir is estimated to be four days under regulated flow conditions. However, supply can often be made directly at the weirs without waiting for water to arrive from storages.

Travel time from the Goulburn Weir to the Shepparton Irrigation Area outfalls to Broken Creek is less than 24 hours following channel automation. Travel time from Yarrawonga Weir to the Murray Valley Area outfalls is two to four days. This should be reduced to less than 24 hours when the channels are automated over the next few years.

Travel times within the Lower Broken Creek itself are defined in the existing FORTRAN model as:

- Four days from the East Goulburn Main channel outfall to Nathalia Weir.
- Six days from Nathalia Weir to Rice's Weir (and therefore ten days from the East Goulburn Main channel outfall to Rice's Weir).

However, some flow can be provided from Shepparton channel 12 and some Murray Valley outfalls directly to Nathalia Weir pool or further downstream, eliminating the four day travel time. The weir pools themselves can also be manipulated in harmony to reduce the six day travel time to less than one day.

The long travel times from the top to bottom of the Lower Broken Creek system means the peaks of high flow events recorded at the upstream end of the study area are attenuated by the time they reach Rice's Weir (Figure 9).

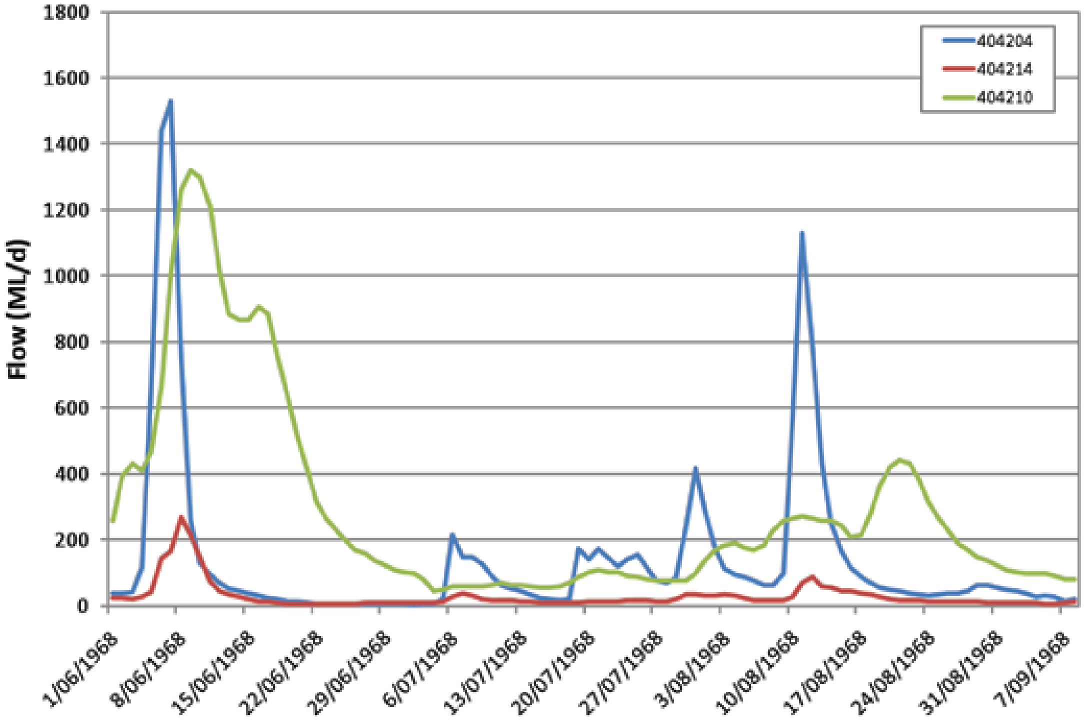

Figure 9: Attenuation of high flow events as they move from the upstream end of the study area (404204 – Boosey Creek at Tungamah and 404214 – Broken Creek at Katamatite) to the downstream end (404210 – Broken Creek at Rice's Weir).

For deliveries using the channel system, G-MW requires an order four days in advance to guarantee the delivery, although flows have been provided in one to two days in response to urgent requests (for example, to address falling levels of dissolved oxygen). If the provision of environmental water was to occur in line with standard ordering procedures, a minimum of four days notice would be required for deliveries.

5.5 Storage releases

The peak thresholds of environmental flow recommendations for the Lower Broken Creek are up to 250 ML/d (Water Technology 2010). Storage release capacities from Murray River and Goulburn headwork storages are not a constraint to delivering these flow magnitudes.

5.6 Channel capacity

Of the regulated inflows to the Lower Broken Creek, the major sources are the East Goulburn Main Channel outfall and the Murray Valley 7/3 channel outfall. The Murray Valley 7/3 channel is a spur channel of the Yarrawonga Main Channel.

Channel capacity constraints can occur seasonally within both the Shepparton and Murray Valley Irrigation Area channel systems. Competition with consumptive (irrigation) demands may pose a significant constraint. Additionally, the channel systems generally do not operate from mid-May to mid-August.

Approximate spare delivery capacities (ML/d) in the Yarrawonga Main channel at the Yarrawonga Weir offtake are shown in Figure 10. Similar plots for the East Goulburn Main Channel offtake from Goulburn Weir and the East Goulburn Main Channel downstream of the siphon are shown in Appendix 2. The data is shown as a range of spare channel capacity over a range of allocations around the defined climate years. Note that there is a difference between low allocation years (with limited irrigation water to deliver and hence spare channel capacity) and dry climate years (where there is low catchment runoff and high environmental demand, but could still be very high allocations from water stored in previous years).

This data highlights, for example, that in a very dry year there is likely to be ample capacity in these main channels to deliver environmental water to the Lower Broken Creek. In dry, median and wet years, the Yarrawonga Main Channel is often at capacity. Along the East Goulburn Main Channel (which has historically delivered the bulk of water to the Lower Broken Creek), there is likely to be limited spare capacity during the irrigation season in median and wet years.

Spare channel capacity in the spur channels and outfalls to the Lower Broken Creek have not been presented because this data was not readily available. However, significant capacity constraints may exist, particularly through the Murray Valley system. A model of the Lower Broken Creek over a long climatic sequence is required to estimate spare outfall capacity. Further analysis of gauged data on the outfalls could be used to identify any recent capacity constraints, which are likely to be representative of spare capacity in dry and very dry years.

The analysis in this section is based on recent past (modelled) conditions, including recent past patterns and volume of demands. More recent changes, including trade out of the Shepparton Irrigation Area and changed patterns of water use from summer pastures to spring and autumn annual pastures due to drought conditions, may affect channel capacity constraints into the future. It is likely that the shift from summer pastures to spring and autumn pastures will reduce capacity constraints (free up capacity) during summer but increase capacity constraints in spring and autumn.

Additionally, channel capacity in Yarrawonga Main Channel and channels through the Murray Valley Irrigation Area may change in the future if there are any changes to Murray River operation around the Barmah Choke. It is likely that this would result in an increase in baseflow to the Lower Broken Creek if the capacity of delivery channels around the choke is increased.

Goulburn-Murray Water should be consulted if the Shepparton or Murray Valley Irrigation Area channel system is to be used to deliver environmental water, to check the likelihood of spare capacity at any given time.

It should be noted that the ability to deliver environmental water via the Murray Valley system is also limited by constraints on water trading. From Zone 7 (Victorian Murray Dartmouth to Barmah) trade is limited to allocation trade up to the volume of back trade to date (no entitlement trade can occur).

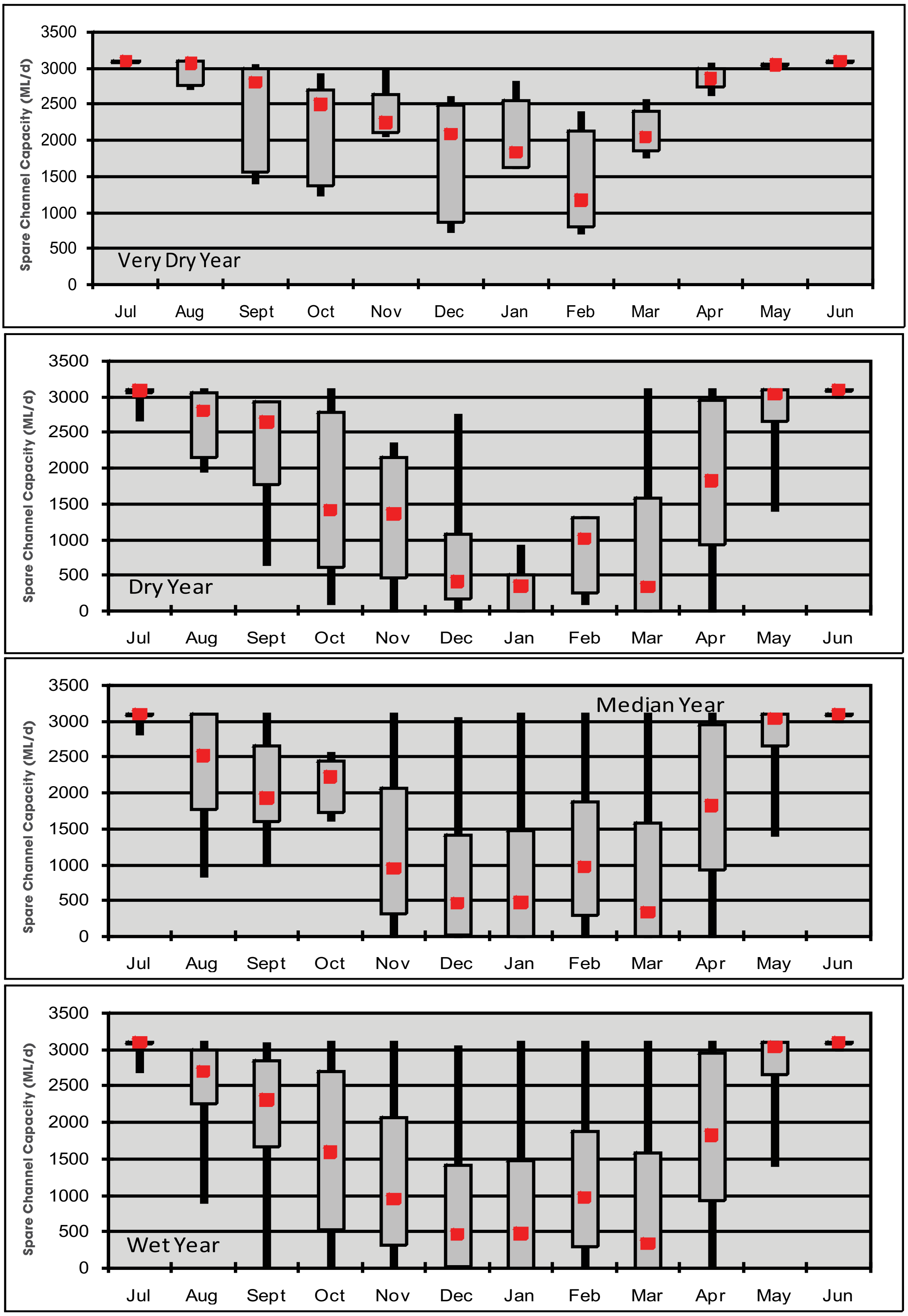

Figure 10: Spare channel capacity in the Yarrawonga Channel offtake, 1895–2009.

The Murray Valley Irrigation Area is being upgraded as part of the Northern Victoria Irrigation Renewal Project (NVIRP). NVIRP plans to reduce the current number of outfall structures that discharge directly from the Murray Valley Irrigation Area to the Lower Broken Creek from 11 to 4, and reduce the volumes supplied above customer requirements by 85 per cent (Water Technology 2010).

Whether the reduction in the number of outfalls from the Murray Valley Irrigation Area to the Lower Broken Creek will reduce or increase the combined outfall capacity, or the ability to deliver environmental water, is unknown at the time of writing. All outfall structures on the Shepparton side of the Lower Broken Creek are being retained.

5.7 Flooding

The baseflow recommended ranges from 40 ML/d up to 250 ML/d. Flows of this magnitude in Lower Broken Creek are delivered via the irrigation channel system and would not be expected to cause any flooding.

5.8 Interaction with other assets

Broken Creek is linked to both the Murray and Goulburn systems via the Yarrawonga Main and East Goulburn Main channels respectively.

Outflows from Broken Creek will contribute to flows in the Murray River downstream of the Barmah Choke. As such, deliveries of water to the Lower Broken Creek can interact with downstream ecological assets on the Murray River, such as Gunbower forest.

Delivering water to the Lower Broken Creek represents an alternative flow path around other ecological assets. Water diverted to the Lower Broken Creek from the Goulburn system may have otherwise flowed through the Lower Goulburn floodplain while water diverted from the Murray system may have otherwise flowed through the Barmah-Millewa forest (depending on river flow rates for both alternative assets). It is noted, however, that environmental water is unlikely to be required for Broken Creek at times when the Lower Goulburn floodplain or the Barmah-Millewa forest are in flood.

5.9 Water delivery costs

5.9.1 Delivery costs

To deliver environmental water to the Lower Broken Creek use of the channel system is required. If environmental water is delivered via the G-MW channel networks, there is an annual service point fee of $200 per service point, plus delivery fees of $11.35 per ML delivered through the Shepparton Irrigation Area and $5.48 per ML delivered through the Murray Valley Irrigation Area. It should be noted that these rates are for interruptible supply, which is only available when there is spare capacity. If guaranteed access is required, the environmental water manager would need to purchase delivery shares which would incur different fees and charges.

Storage charges are also applicable. 2011–12 storage costs for the Goulburn system are $3.54 per ML held in the spillable water account, $6.98 per ML of high reliability water share and $3.54 per ML of low reliability water share. Storage costs for the Victorian Murray system are $4.56 per ML held in the spillable water account, $10.16 per ML of high reliability water share and $4.56 per ML of low reliability water share.

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.

It is assumed that any water sourced from NSW water shares for delivery to the Lower Broken Creek system would first be transferred to a Victorian Murray or Goulburn system account and that Goulburn-Murray Water's delivery costs would apply.

5.9.2 Carryover costs

The 2011–12 fees for transferring water from the spillable water account back to the allocation bank account is $4.52 per ML for the Victorian Murray system and $3.52 per ML for the Goulburn system. See http://www.g-mwater.com.au/customer-services/carryover#1 for more info.

6. Governance

6.1 Water planning responsibilities

The Northern Region Sustainable Water Strategy (NRSWS) provides the strategic direction for water management across northern Victoria (DSE 2009). The NRSWS also presents the community with an agreed level of health target for Victoria's northern rivers. The Victorian Government has agreed to try and meet the health target through various mechanisms, including through the use of environmental water.

Much of the riparian zone is managed by Parks Victoria as part of the Broken-Boosey State Park Management Plan (Parks Victoria 2006). G-MW has responsibility for the planning and delivery of water to the Lower Broken Creek. In doing so, G-MW collaborates with:

- The GB CMA to deliver environmental water, including the Goulburn Water Quality Reserve and inter-valley transfers through Lower Broken Creek. NOTE: while G-MW can make recommendations regarding the delivery of inter-valley transfers to support GB CMA objectives, the actual delivery of inter-valley transfers is governed by the MDBA who are working towards the management of the larger Murray-Darling Basin and are not compelled to follow G-MW's recommendations.
- The Victorian Environmental Water Holder, who is responsible for managing the Victorian government's environmental water entitlements and allocations, and for making decisions on the use of Victorian environmental water.
- The Murray-Darling Basin Authority to manage Murray River rainfall-rejections around the Barmah Choke, by redirecting water from the Murray River at Yarrawonga to the Lower Broken Creek via the Murray Valley Irrigation Area channel system. MDBA may direct water through the Murray Valley Irrigation Area at the request of G-MW to assist with water quality in Broken Creek.

Environmental water holdings in the Murray River and Goulburn systems can be delivered from the Murray River headworks storages (Hume or Dartmouth Reservoirs) or Goulburn headworks storage (Eildon Reservoir, Goulburn Weir).

6.2 Delivery partners, roles and responsibilities

The major strategic partners in delivering water to assets within the Lower Broken Creek include:

- GB CMA as the manager of the Environmental Water Reserve for the Goulburn system.
- G-MW as the Bulk Entitlement holder and manager of the major reservoirs in the catchment, manager of the Shepparton and Murray-Valley Irrigation Areas and also the licensing authority responsible for groundwater and surface water licensed diversions.
- Goulburn Valley Water is responsible for urban water supply in the catchment.
- VEWH is responsible for making decisions on the use of Victorian environmental water.

Both the GB CMA and G-MW cooperate with VEWH in the delivery of environmental water, as well as with the MDBA in relation to water transfers (inter-valley transfers) from the Murray system.

6.3 Approvals, licences, legal and administrative issues

6.3.1 Water shepherding and return flows

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 losses (if any) are taken into account.
- The return flows can be delivered in line with the timing requirements of the downstream user, purchaser or environmental site.
- The system operator can re-regulate the return flows downstream, with a known and immaterial spill risk, if the entitlement holder is requesting credits on a regulated system.

The Australian Government does not currently have the ability to deliver water from its water shares, so it must transfer its allocations to the VEWH for them to be used. If Commonwealth environmental water allocations are transferred to the environmental entitlements held by the VEWH, then the ability to reuse the return flows in the Murray River depends on the conditions of the individual entitlement.

For Broken Creek, water entering the Murray River from Broken Creek is treated as a Victorian tributary inflow under the Murray-Darling Basin Agreement. Credits for this water may be granted if the Murray-Darling Basin Authority determines that the inflows have added to usable resources. If tributary credits are granted, the water is added to Victorian resources and falls under the provisions of the Murray Bulk Entitlement. Environmental water managers would need an agreement with G-MW to have these return flows credited to their allocation bank account for the Murray River downstream of the Barmah Choke. The re-crediting of return flows may require agreement from all three States.

If Murray River water shares were transferred to the VEWH's Flora and Fauna entitlement, then return flows from Broken Creek to the Murray River can more readily be credited under Clause 15 of the entitlement. Specified points for return flows are listed in Schedule 4 to the entitlement, which currently does not include return flows from Broken Creek. 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 Murray-Darling Basin Authority.

If the point of delivery for environmental water is specified as Rice's Weir, which is at the outlet of Lower Broken Creek, this ensures that the most downstream reaches of Lower Broken Creek receive the required baseflows. However, G-MW could choose to deliver this water through the most downstream outfalls, in which case the upper reaches of Lower Broken Creek would not receive environmental benefit. In practice this is unlikely, because there is generally less spare capacity in these outfalls than further upstream. Alternatively, if the point of delivery for environmental water is specified as the outfall of the East Goulburn Main Channel, which is at the upper end of Lower Broken Creek, this would provide environmental flows in this upper reach. However, there would be no guarantee that the water would be shepherded through the various diversion weirs along Lower Broken Creek. It is recommended that environmental water managers discuss this issue further with G-MW if deliveries are to be made to Lower Broken Creek, to ensure, as best as possible, that the desired baseflows are delivered along the length of the Lower Broken Creek. In the absence of more specific advice from G-MW, ordering water at Rice's Weir is likely to achieve the most environmental benefit.

6.4 Trading rules and system accounting

6.4.1 Water trading

Trading zone boundaries are shown in figure 11.

The Lower Broken Creek system is located in Trading Zone 6B (Lower Broken Creek).

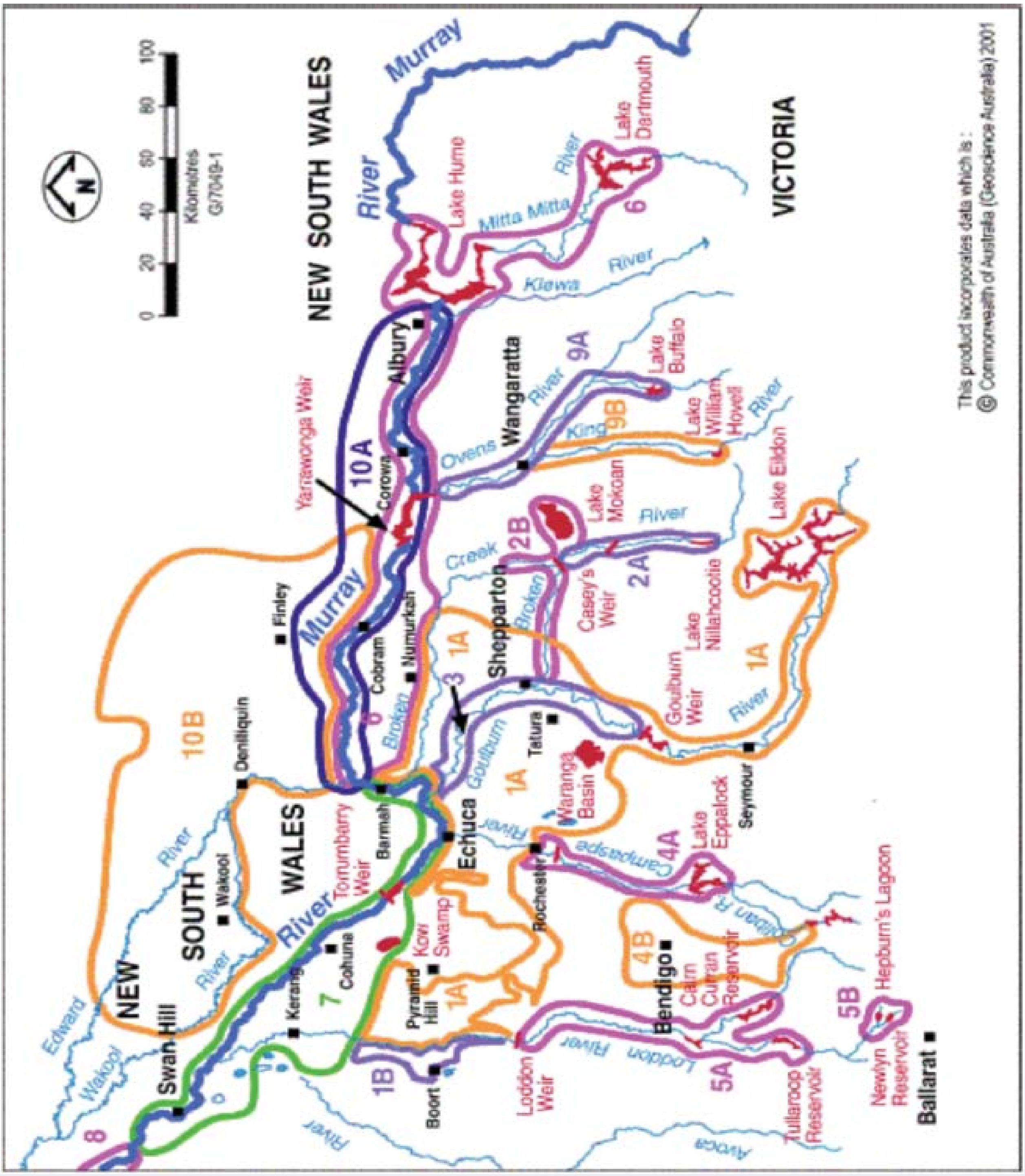

Figure 11: Trading zone boundaries (Source: http://www.watermove.com.au).

Table 8: Summary of trading between zones (Source: SEWPaC 2011).

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

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

Additional Trading Rules

All trade, except trading to unregulated tributaries, is with an exchange rate of 1.00. Trade into unregulated river zones (zone 170) can only be transferred as a winterfill licence, which only becomes available in the following year. The water share volume is increased by 19 per cent when transferred to a winterfill licence, and decreased by 19 per cent when bought from a winterfill licence. Trade (of allocation or entitlement) into Murray Irrigation Limited areas (zone 10B) attracts a 10 per cent loss of share volume.

Permanent trade is currently limited to 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. For more information on water trading rules see the Victorian Water Register (http://waterregister.vic.gov.au/).

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

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

This means that any allocation trades must be made well in advance of a targeted runoff event.

Water trading attracts water trading fees. If trading is conducted without the use of a broker, the fees are currently less than $80 for Victorian within State trade. See the Victorian Water Register for Victorian fee schedules at http://waterregister.vic.gov.au/Public/ApplicationFees.aspx.

6.4.2 Water storage accounting

The Lower Broken Creek system does not have any water storages. Water storage accounting for the Victorian Murray system and the Goulburn systems is annual water accounting (July to June) with some carryover.

In the Victorian Murray and Goulburn systems, unlimited storage carryover is allowed, but water above 100 per cent of the water share volume can be quarantined in a spillable water account when there is risk of spill. Any carryover in the spillable water account cannot be accessed until the risk of spill has passed. If a spill occurs, carryover is the first to spill. Annual deduction for evaporation is 5 per cent of carried over volume.

The fees for transferring water from the spillable water account back to the allocation bank account can be found in section 5.9.2. For more information on carryover, see http://www.g-mwater.com.au/customer-services/carryover/lbbcarryover/.

7. Risk assessment and mitigation

The risk assessment outlined in Table 9 provides an indication of the risks associated with the delivery of environmental water in the Lower Broken Creek 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. A framework for assessing risks has been developed by SEWPaC and is included at Appendix 4.

Table 9: Flow-related risks to environmental objectives for the Lower Broken Creek system.

Risk type	Description	Likelihood	Consequence	Risk level	Controls
Acid sulphate soils	There is no evidence of acid sulphate soil issues along Broken Creek.	Unlikely	Moderate	Low	Maintenance of continuous flows should minimise this risk.
Salinity	Releases from the Murray and Goulburn Rivers are of good quality and do not pose salinity risks at the volumes proposed.	Unlikely	Minor	Low	Salinity is monitored and the Goulburn Water Quality Reserve could be called upon to reduce (dilute) saline water, if this was necessary (highly unlikely).
Invasive species	Carp breeding can occur, along with that of native fish. The introduced fish weatherloach and gambusia are also present. The aquatic weed *Sagittaria* sp. (arrowhead) has also occurred.	Likely	Moderate	Medium	None for alien fish species. The control and eradication of arrowhead is an ongoing management issue for G-MW and the GB CMA.
Low DO (e.g. from blackwater events)	Fish kills have resulted from low DO, often associated with Azolla outbreaks and low flows in summer. Current management practices are aimed at addressing these contributing factors. Low DO and blackwater events can also arise from overland flooding from the upstream catchment.	Possible	Major	High	Monitor DO at Rice's Weir and track trends in data to ensure a drop in DO levels is noticed in time for action to be taken to prevent negative impacts. Maintain sufficient flow through of water to minimise Azolla build up in winter-spring, and to avoid low DO in summer-autumn.
Limited access to channel capacity	Releases to meet consumptive demand may constrain the capacity available for delivering environmental flows.	Possible/likely	Minor	Medium	Risk may be offset by the delivery of consumptive water.
Reduced discharge to Lower Broken Creek from channel outfalls and Upper Broken Creek due to modernisation and the Tungemah pipeline.	Reduced outfalls may reduce discharge to the creek.	Possible	Moderate	Medium	Adjust releases to account for reduced inflows from channel outfalls and Upper Broken Creek.
Water loss	The magnitude of losses along the Lower Broken Creek system are unknown.	Likely	Minor	Medium	Review losses along Broken Creek. Allow for losses, if necessary, when estimating allocations.
Other considerations	Reliance on modeled flows at Rice's Weir, which may underestimate the volume of water required to meet objectives.	Possible	Moderate	Medium	Develop contingencies for increasing discharge if required.

8. Environmental water reserves

8.1 Environmental water holdings and provisions

8.1.1 Environmental water provisions

G-MW's 'Monitoring and Incident Response Manual' (2004) made note of an agreement between G-MW and the MDBA (then the River Murray Commission) to provide a 40 ML/d allocation to the Lower Broken Creek (via the Murray Valley channel system) to manage water quality (Azolla build up). In 2003–04 the agreement was modified to 80 ML/d. The current status of this agreement is unknown, but it is believed to no longer be active (Water Technology 2010). Excluding the above, there are no planned environmental water provisions for the Lower Broken Creek. However, in recent years significant water deliveries have been made to manage water quality. These provisions have come from a number of sources:

- Water from the Goulburn Water Quality Reserve (Eildon-Goulburn Weir BE 1995) via the Shepparton Irrigation Area channel system.
- Inter-valley transfers from the Goulburn system to the Murray River system through the Shepparton Irrigation Area channel system and Lower Broken Creek (rather than directly down the Goulburn River).
- Water from the Murray Flora and Fauna BE (1999) via the Murray Valley Irrigation Area channel system (which may also be back traded to the Goulburn system and delivered via the Shepparton Irrigation Area channel system).
- Murray River water diverted to bypass the Barmah-Millewa forest.

Table 10 describes how the 30,000 ML Goulburn Water Quality Reserve has been used to manage water quality in the Lower Broken Creek.

Table 10: Goulburn Water Quality Reserve History.

Year	Volumes and purpose of use
2004–05	0
2005–06	513 ML was delivered to the Broken Creek to assist water quality.
2006–07	422 ML was delivered to the Broken Creek. 7,000 ML released onto the Goulburn water market for purchase by local irrigators and urban corporations.
2007–08	1,878 ML was used in the Broken Creek to assist water quality. 10,000 ML supplied to Coliban Water and Central Highlands Water to supplement existing supplies and meet critical water shortages in Bendigo and Ballarat.*
2008–09	2,817 ML was used in the Broken Creek to assist natural break up of a weed infestation (Azolla) and improve dissolved oxygen concentrations. 10,000 ML supplied to Coliban Water and Central Highlands Water to supplement existing supplies and meet critical shortages in Bendigo and Ballarat.*
2009–10	818 ML used to stabilise dissovled oxygen concentrations in the low Broken Creek. 10,000 ML supplied to Melbourne via the Sugarloaf Pipeline (in accordance with Qualification of Rights).

* Coliban Water and Central Highlands Water paid commercial rates for access to additional water, with pricing arrangements agreed by the Minister for Water in accordance with the Qualification of Rights (http://www.g-mwater.com.au/about/reports-and-publications/annualreport/operations-division)

8.1.2 Current water holdings

Commonwealth environmental water holdings (as at October 2010) are summarised in Table 11. Water shares can only be used if sufficient channel capacity to deliver the entitlements is available in the Shepparton or Murray Valley channel systems, because the Australian Government does not hold delivery shares. It should be noted that volumes of Commonwealth environmental water are constantly changing. For the most up to date figures see www.environment.gov.au/ewater.

Figures in Table 11 are based on allocation information from MSM-Bigmod modelling of the Murray River system with The Living Murray deliveries in place (run #22061).

Environmental water currently held by other agencies is summarised in Table 12.

Table 11: 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	
	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.

Table 12: Environmental water currently held by other agencies.

Water holding	Volume	Comments
Victorian River Murray – **Flora and Fauna** Conversion Order 1999	27,600 ML high reliability water share.	Total available upstream and downstream of the Choke.
Victorian River Murray – Flora and Fauna Conversion Further Amending Order (2009) – **The Living Murray**	40,298 ML low reliability water share. 3,630 ML high reliability water share.	Committed to meet Living Murray objectives but may be useful in transit.
The Living Murray – NSW Murray system	1,887 high security. 134,387 general security. 350,000 ML supplementary. 12,965 ML unregulated.	Unclear how much of this is above or below the Choke. Committed to meet Living Murray objectives, but may be useful in transit.
Environmental Entitlement (Goulburn System – Living Murray) Further Amending Order 2009	141,046 ML of low reliability water shares (sales package). 19,164 ML of high reliability water shares (G-MW recovery package). 20,461 ML of high reliability water shares (Shepparton Irrigation Area modernisation project). 15,780 ML of low reliability water shares (Shepparton Irrigation Area modernisation project).	Committed to meet Living Murray objectives, but may be useful in transit.
Bulk Entitlement (Goulburn System – Snowy Environmental Reserve) Amendment Order 2009	3,900 ML of high reliability water share (pipelining of Normanville waterworks district). 14,812 ML of high reliability water share (Goulburn system improved measurement of small volume supplies to irrigation districts program). 2,000 ML of high reliability water share (Goulburn strategic measurement project).	Generally released along the Goulburn River in summer to supply Murray irrigation demands.
Goulburn River Environmental Entitlement 2010	1,432 ML of high reliability water share (Wimmera-Mallee Pipeline Savings).	Trading zone 1B.
Environmental Entitlement (Goulburn System – Environmental Water Reserve) 2010	Prior to the completion of Stage 1 of the Northern Victoria Irrigation Renewal Project: the volume of water that has been allocated to the environment from the modernisation savings account. After the completion of Stage 1: the volume equivalent to one-third of the total volume saved in the Goulburn component of the Goulburn Murray Irrigation District, with the characteristics of high reliability and low reliability water shares.	Exact volumes to be confirmed after completion of NVIRP works. This entitlement was gazetted but was disallowed in the Victorian Parliament in June 2010.

8.2 Seasonal allocations

Victorian allocations are announced by Goulburn-Murray Water twice monthly 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 Figures 12 and 13. This information is sourced from the MSM-Bigmod post-TLM run (#22061). These figures indicate that Goulburn system reliability is lower than that of the Victorian Murray system and that the NSW and Victorian Murray systems have slightly different allocation profiles.

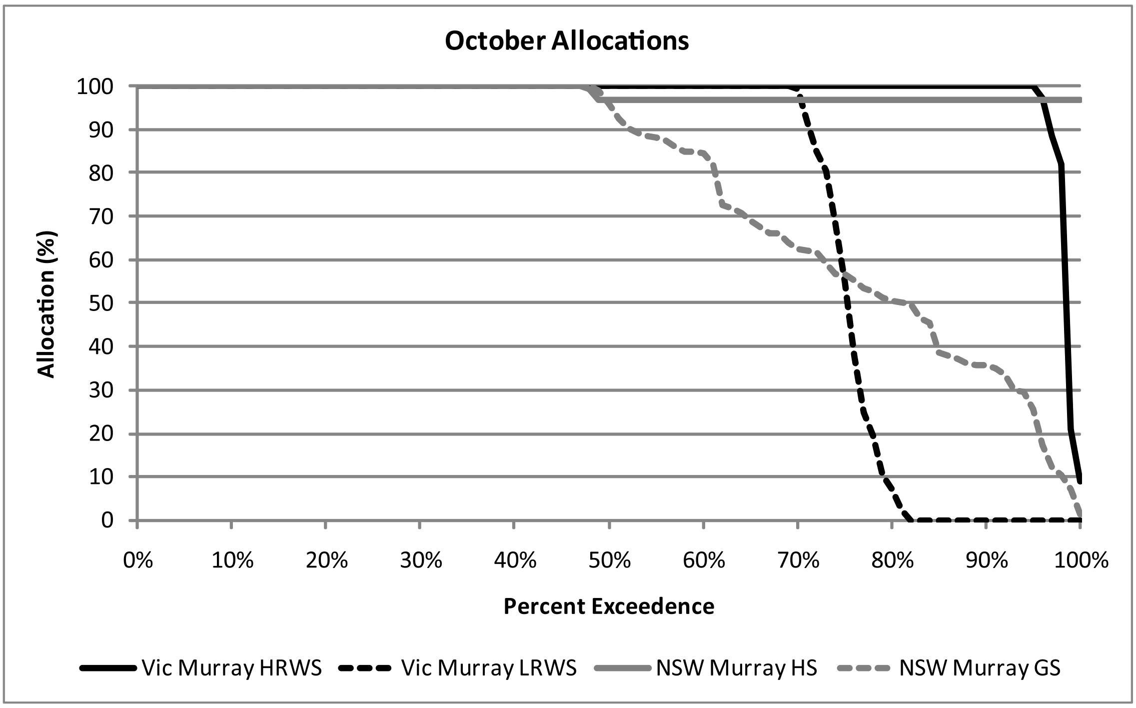

Figure 12: October seasonal allocations for the Murray River and Goulburn systems.

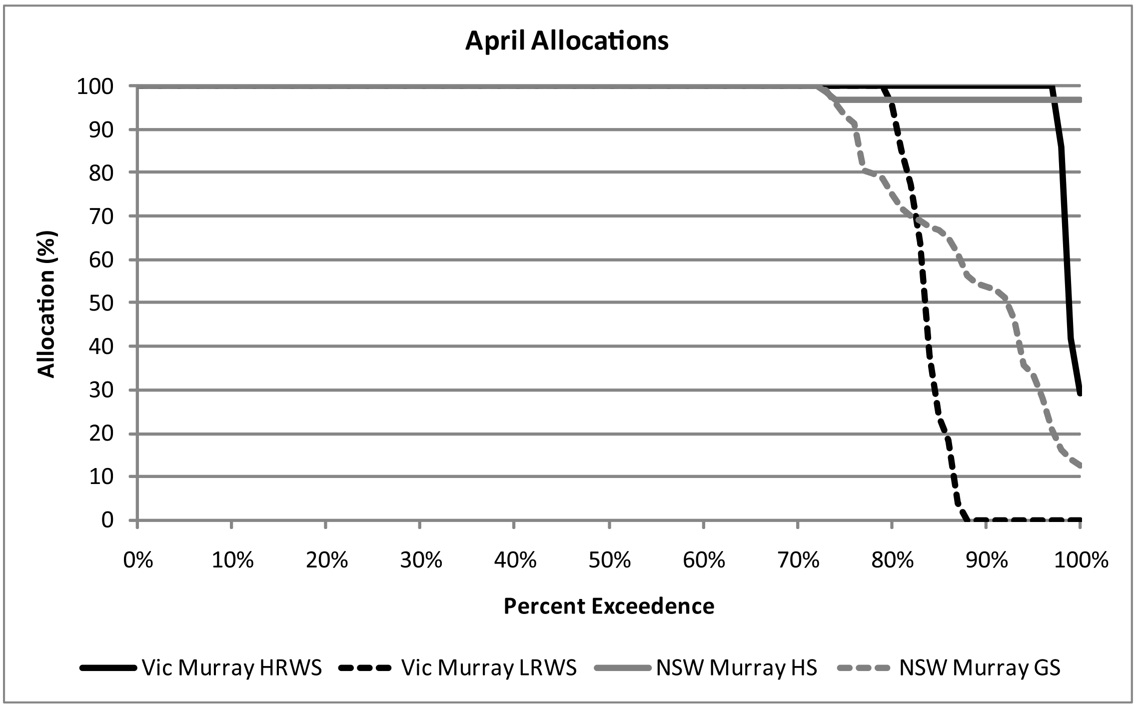

Figure 13: April seasonal allocations for the Murray River, Goulburn and Ovens systems.

The allocation expected to be available (in terms of announced allocation) to the environment under different climate conditions is summarised in Table 13. The volume of water expected to be available to the environment under different climate conditions is summarised in Table 14.

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).

Table 13 and Table 14 were provided by SKM and based on allocation information from a MSM-Bigmod model of the Murray River system with The Living Murray deliveries in place (run #22061).

Table 13: Likely allocation against 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	100
Broken	High reliability water share	20.0	1	96	97	98	1	100	100	100
	Low reliability water share	4.2	0	0	0	0	0	100	100	100
Campaspe	High reliability water share	5,124.1	33	100	100	100	43	100	100	100
	Low reliability water share	395.4	0	100	100	100	0	100	100	100
Loddon	High reliability water share	1,179.0	0	100	100	100	0	100	100	100
	Low reliability water share	527.3	0	2	54	96	0	16	78	100
South Australia	High reliability	43,297.4	44	100	100	155	62	100	100	102

Table 14: Likely volume available to the environment from 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
Campaspe	High reliability water share	5,124.1	1.7	5.1	5.1	5.1	2.2	5.1	5.1	5.1
	Low reliability water share	395.4	0.0	0.4	0.4	0.4	0.0	0.4	0.4	0.4
Loddon	High reliability water share	1,179.0	0.0	1.2	1.2	1.2	0.0	1.2	1.2	1.2
	Low reliability water share	527.3	0.0	0.0	0.3	0.5	0.0	0.1	0.4	0.5
South Australia	High reliability	43,297.4	19.0	43.3	43.3	66.9	26.6	43.3	43.3	44.3
Total below Barmah Choke			**48.1**	**247.4**	**272.3**	**307.7**	**80.8**	**278.1**	**305.6**	**309.0**
Total			**53.2**	**382.6**	**459.5**	**501.5**	**109.5**	**471.8**	**499.4**	**502.8**

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

8.3 Water availability forecasts

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

Water quality and quantity is monitored as part of the Victorian Water Quality Monitoring Network. As well as flow monitoring at the three sites listed in Table 15, water quality parameters are measured on a monthly basis at Rice's Weir (site 404210) and Katamatite (site 404214). Parameters measured include: colour, dissolved organic carbon, dissolved reactive phosphorus, electrical conductivity, total Kjeldahl nitrogen, oxidised nitrogen, pH, total phosphorus and turbidity.

In addition, the GB CMA undertakes continuous DO monitoring at Rice's Weir. Two sets of probes, each monitoring surface and bottom DO and temperature, are deployed to provide spatial coverage of conditions in the weir. This allows the GB CMA and G-MW to respond to the onset of low DO conditions by increasing flow delivered to the Lower Broken Creek from the Murray River via the Murray Valley Irrigation Area, or from the Goulburn River via the East Goulburn Main Channel. Wind speed and direction and air temperature are also recorded, along with hourly photographs of Azolla disposition.

Goulburn-Murray Water also has dissolved oxygen and temperature probes at Rice's Weir and Hardings Weir.

Fishways have been established at all weirs along Lower Broken Creek between Nathalia and the Murray River and at the two weirs at Katandra. Fish populations along the creek have been monitored for a number of years to assess the effectiveness of the fishways in allowing movement, as well as the changes to the distribution of fish as a result (O'Connor and Amtstaetter 2008).

The Victorian Environmental Flows Monitoring and Assessment Program (VEFMAP) was established to evaluate ecosystem response to the delivery of environmental flow components in regulated rivers across northern Victoria. While the Broken River was included in VEFMAP (Chee et al. 2006), Lower Broken Creek was not, as there were no specific environmental flow recommendations for the creek at the time VEFMAP was developed.

9.2 Operational water delivery monitoring

Water delivery monitoring arrangements are summarised in section 9.2.1. In addition, the Department of Sustainability, Environment, Water, Population and Communities (SEWPaC) has a pro forma Environmental Watering Program Operational Monitoring Report to capture operational information related to releases (included at Appendix 3).

9.2.1 Flow monitoring sites

Three long-term stream flow gauges are located within the Lower Broken Creek area (Table 15). The Boosey Creek at Tungamah (404204) and Broken Creek at Katamatite (404214) gauges are located upstream of the confluence of the Broken Creek and Boosey Creek, while the Broken Creek at Rice's Weir (404210) gauge is located upstream of the confluence with the Murray River.

The flow records for each of the three gauges begin in the mid-1960s (Figure 14; Figure 8). The records for the Boosey Creek at Tungamah and the Broken Creek at Katamatite are generally of good quality. In contrast, there is much data missing from the Broken Creek at Rice's Weir record. Some of these missing periods coincide with floods along the Murray River, when water would have backed up Broken Creek and drowned out the gauging station.

The MDBA can also supply a daily time-series of modelled flows past Rice's Weir, assuming current conditions. The current modelled time-series provided is a combination of gauged and infilled data.

Table 15: Flow monitoring in the Lower Broken Creek system.

Site number	Site name	Relevance
404204	Boosey Creek at Tungamah	Flow from Boosey Creek to Lower Broken Creek
404214	Broken Creek at Katamatite	Flow from Upper to Lower Broken Creek
404210	Broken Creek at Rice's Weir	Flow from Broken Creek to Murray River

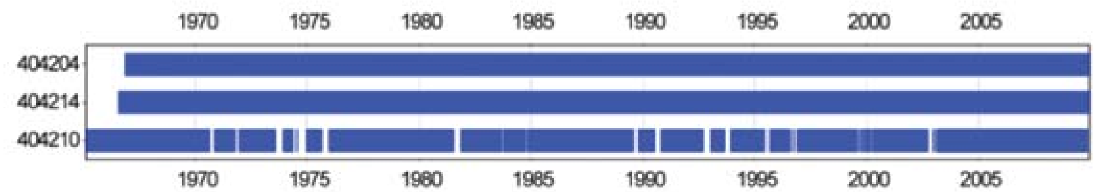

Figure 14: Extent of streamflow data available.

Goulburn-Murray Water have measured flows under regulated conditions passed though each weir on a continuous basis, commencing in the late 1990s to early 2000s.

Data on inflows to the Lower Broken Creek and Nine Mile Creek through outfall structures and drains are available from Goulburn-Murray Water and Thiess (Table 16 and Table 17). For the outfalls, data is only readily available for irrigation seasons from 1997–98 onwards. The 2000–2001 data is missing for the Murray Valley Irrigation Area, and the 1998–99 data is missing for the Shepparton Irrigation Area. For the drains, gauged data is available for the Muckatah drain, Shepparton Drain 12 and Shepparton Drain 11. No data is available for the remaining drains.

Table 16: Outfall structures currently discharging directly to the Lower Broken Creek and Nine Mile Creek. Some structures will be decommissioned as part of NVIRP works (Figure 1).

Asset Code	Asset Name	Data Source
ST066229	7/3	G-MW (Murray Valley)
ST072180	3 Main	G-MW (Murray Valley)
ST041815	4 Main	G-MW (Murray Valley)
ST057773	5/3	G-MW (Murray Valley)
ST056529	6/6	G-MW (Murray Valley)
ST056668	8/6	G-MW (Murray Valley)
ST056597	4/8/6	G-MW (Murray Valley)
ST066584	15/6	G-MW (Murray Valley)
ST058403	Jewells (21A/6)	G-MW (Murray Valley)
ST056428	Flanners (26A/6)	G-MW (Murray Valley)
ST056447	End 6 Main	G-MW (Murray Valley)
ST043762	EGM Outfall	G-MW (Shepparton)
ST018998	EG.34 Union Rd	G-MW (Shepparton)
ST019005	EG.34 End	G-MW (Shepparton)
ST045754	EG.12 No 1 (Hicks)	G-MW (Shepparton)
ST046200	EG.38/12 Town Spur	G-MW (Shepparton)
ST045802	EG.12 No 2 (Hollands)	G-MW (Shepparton)

Table 17: Drains discharging to the Lower Broken Creek and Nine Mile Creek.

Asset Name	Data Source
Muckatah Drain	Thiess (404712)
Murray Valley Drain 20	Not available
Murray Valley Drain 19	Not available
Murray Valley Drain 18	Not available
Murray Valley Drain 17	Not available
Murray Valley Drain 13	Not available
Shepparton Drain 16	Not available
Shepparton Drain 15	Not available
Shepparton Drain 13	Not available
Shepparton Drain 13A	Not available
Shepparton Drain 12	Thiess (405758)
Shepparton Drain 11	Thiess (405757)

9.3 Key parameters for monitoring and evaluating ecosystem response

The environmental management objectives for Lower Broken Creek are to maintain water quality in order to protect native fish populations. Monitoring of Azolla, DO and flow through the system is well established. The information being collected also complements scientific research on the conditions that lead to the onset of stratification and decline in DO along the Lower Broken Creek.

The flow regime proposed for Lower Broken Creek also aims to maintain habitat for native fish and allow fish passage through weirs. Fish populations are currently monitored to assess the extent to which fish are moving through the fishways and colonising different sections of the creek.

9.4 Improved understanding of DO processes

The Murray-Darling Freshwater Research Centre has investigated the growth of Azolla and factors that contribute to dissolved oxygen levels in weir pools along Lower Broken Creek (Rees et al. 2008). This work found that sediment oxygen demand was high in locations such as Rice's Weir and that DO could be reduced close to 0 mg/L at depth. The presence of Azolla exacerbated the DO decline.

It is not clear if the recent (October 2010) high flows have had an effect on the sediments in weir pools along Broken Creek, and if this in turn has affected sediment oxygen demand. Such investigation, along with that of nutrient load and nutrient dynamics, could result in an improved understanding of the factors contributing to low DO in the creek, as well as an understanding of whether managing the flow regime remains the most effective means of managing water quality.

10. Bibliography

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11. Appendix 1: Key species and communities

Table 18: Key species in the Lower Broken Creek system.

Fauna type	Common name	Scientific name	EPBC Act[1]	Flora and Fauna Guarantee Act[2]	DSE advisory list[3]	Waterway setting[4]
Fish	Bluenose (Trout) cod	*Maccullochella macquariensis*	Endangered	Listed	Critically endangered	-
Fish	Freshwater catfish	*Tandanus tandanus*	-	Listed	Endangered	-
Fish	Golden perch	*Macquaria ambigua*	-	-	Vulnerable	-
Fish	Unspecked hardyhead	*Craterocephalus stercusmuscarum fulvus*	-	Listed	Data deficient	-
Fish	Macquarie perch	*Macquaria australasica*	Endangered	Listed	Endangered	-
Fish	Murray cod	*Maccullochella peelii peelii*	Vulnerable	Listed	Endangered	-
Fish	Silver perch	*Bidyanus bidyanus*	-	Listed	Critically endangered	-
Amphibians	Giant bullfrog	*Limnodynastes interioris*	-	Listed	Critically endangered	-
Amphibians	Growling grass frog	*Litoria raniformis*	Vulnerable	Listed	Endangered	-
Plants	Slender water-milfoil	*Myriophyllum gracile var. lineare*	-	Listed	Endangered	Aquatic
Plants	Ridged water-milfoil	*Myriophyllum porcatum*	Vulnerable	Listed	Vulnerable	Aquatic
Plants	Slender water-ribbons	*Triglochin dubia*	-	-	Rare	Aquatic
Plants	Pale spike-sedge	*Eleocharis pallens*	-	-	Poorly known	Seasonally flooded
Plants	Slender club-sedge	*Isolepis congrua*	-	Listed	Vulnerable	Seasonally flooded
Plants	River swamp wallaby-grass	*Amphibromus fluitans*	Vulnerable	-	-	Waterway margin
Plants	Western water-starwort	*Callitriche cyclocarpa*	Vulnerable	Listed	Vulnerable	Waterway margin
Plants	Winged water-starwort	*Callitriche umbonata*	-	-	Rare	Waterway margin

Fauna type	Common name	Scientific name	EPBC Act[1]	Flora and Fauna Guarantee Act[2]	DSE advisory list[3]	Waterway setting[4]
Plants	Riverina bitter-cress	*Cardamine moirensis*	-	-	Rare	Water way margin
Plants	Long eryngium	*Eryngium paludosum*	-	-	Vulnerable	Waterway margin
Plants	Small-flower mud-mat	*Glossostigma cleistanthum*	-	-	Rare	Waterway margin
Plants	Bluish raspwort	*Haloragis glauca f. glauca*	-	-	Poorly known	Waterway margin
Plants	Swamp star	*Hypoxis exilis*	-	-	Vulnerable	Waterway margin
Plants	Button rush	*Lipocarpha microcephala*	-	-	Vulnerable	Waterway margin
Plants	Leafless bluebush	*Maireana aphylla*	-	-	Poorly known	Waterway margin
Plants	Smooth minuria	*Minuria integerrima*	-	-	Rare	Waterway margin
Plants	Striped water- milfoil	*Myriophyllum striatum*	-	Listed	Vulnerable	Waterway margin
Plants	Large river buttercup	*Ranunculus papulentus*	-	-	Poorly known	Waterway margin
Plants	Annual buttercup	*Ranunculus sessiliflorus var. pilulifer*	-	-	Poorly known	Waterway margin

[1] Environment Protection and Biodiversity Conservation Act 1999 (Commonwealth).
[2] Flora and Fauna Guarantee Act 1988 (Victoria).
[3] Advisory List of Rare or Threatened Plants in Victoria – 2005. This list is maintained by the Victorian Department of Sustainability and Environment to inform land management. This is not a statutory list and there are no legal requirements associated with a species' inclusion on the list (DSE 2005, DSE 2007).
[4] Waterway setting was assigned based on species descriptions from PlantNet (Royal Botanic Gardens and Domain Trust 2011).

Table 19: Ecological vegetation classes in the Lower Broken Creek system.

Vegetation Community	Structural Characteristics
56. Floodplain Riparian Woodland	An open eucalypt woodland or open forest to 20 metres tall over a medium to tall shrub layer with a ground layer consisting of amphibious and aquatic herbs and sedges. Occurs along the banks and floodplains of the larger meandering rivers and major creeks, often in conjunction with one or more floodplain wetland communities. Elevation and rainfall are relatively low and soils are fertile alluviums subject to periodic flooding and inundation.
68. Creekline Grassy Woodland	Grass-dominated eucalypt woodland to 15 metres tall with a range of amphibious herbs. Occurs along banks and adjacent wet flats of smaller intermittent creeks on coarse sands and stony alluvial soils and on the floodplains of larger rivers, in areas where annual rainfall is greater than 500 millimetres per annum.

Vegetation Community	Structural Characteristics
74. Wetland Formation	A broad EVC that incorporates a range of freshwater wetlands as listed below in the table. Occurs in topographic depressions associated with standing water ranging from permanent to ephemeral water bodies. Structurally, this EVC can consist of herbland, sedgeland and rushland elements and is characterised by the lack of woody plants (shrubs and trees).
106. Grassy Riverine Forest	Occurs on the floodplain of major rivers, in a slightly elevated position where floods are infrequent, on deposited silts and sands, forming fertile alluvial soils. river red gum forest to 25 metres tall with a groundlayer dominated by graminoids. Occasional tall shrubs present.
125. Plains Grassy Wetland	This EVC is usually treeless, but in some instances can include sparse black box eucalyptus largiflorens or river red gum Eucalyptus camaldulensis. A sparse shrub component may also be present. The characteristic ground cover is dominated by grasses and small sedges and herbs. The vegetation is typically species-rich on the outer verges but is usually species-poor in the wetter central areas.
168. Drainage-line Aggregate	An aggregate of eight EVCs. A detailed description can be found at: http://www.dpi.vic.gov.au/DSE/nrence.nsf/LinkView/47DB7187972C9AD1CA256F1F0022D6DD8062D358172E420C4A256DEA0012F71C#agg
259. Plains Grassy Woodland/Gilgai Wetland Mosaic	N/A
264. Sand Ridge Woodland	Open pine-box woodland to 15 metres tall with a small or medium shrub layer of variable density and including a range of annual herbs, grasses and geophytes, in the dense ground layer. Occupies distinctive sandy rises (or sand mounts) adjacent to major rivers and wetlands. Very sandy, deep, free draining, moderately fertile soil, developed on sand blown up by wind action from a prior stream bed.
292. Red Gum Swamp	Open woodland to 15 metres tall with a diverse understorey dominated by sedgy or grassy-herbaceous aquatics and species tolerant of intermittent to seasonal inundation. Occurs on alluvial plains in the seasonally wet depressions of shallow drainage lines or prior stream meanders, typically associated with heavy paludal soils, sometimes with gilgai development. The annual rainfall across its distribution is generally below 700 millimetres, and the period of inundation may range from two to six months.
803. Plains Woodland	Grassy or sedgy woodland to 15 metres tall (typically dominated by eucalyptus largiflorens in the north-western part of its range) with large inter-tussock spaces potentially supporting a range of annual or geophytic herbs adapted to low summer rainfall, with low overall biomass. Mostly occurs on terrain of low relief in areas receiving <600 millimetres rainfall per annum. Fertile, sometimes seasonally waterlogged, mostly silty, loamy or clay topsoils, with heavy subsoils, derived largely from recent (ie Quaternary) fluvial or alluvial deposits.
814. Riverine Swamp Forest	Open eucalypt forest to 25 metres tall with understorey dominated by obligate wetland species (or opportunistic annuals during sustained dry periods) and can range from closed sedgeland or herbland to grassy-herbaceous or extremely sparse and with cover primarily leaf-litter, blackwater or exposed alluvium. Occupies low-lying areas subject to reasonably regular flooding, typically flood-prone lower river terraces and low-lying areas adjacent to floodways through or within riverine forest.
816. Sedgy Riverine Forest	Eucalypt forest to 25 metres tall with understorey dominated by larger sedges. Understorey composition indicative of at least occasional shallow flooding and a tolerance of gaps between floods of several years. Typically on heavy soils which can become wet in winter. Sedgy Riverine Forest has some floristic affinities to Red Gum Swamp. It is considered to occupy areas infrequently flooded and in which flood duration may be short, for example, higher ground surrounding the box ridges or occurring along the river levee in a position remote from the channels from which the forest first floods. These areas are therefore the last to flood and the first from which floods quickly recede. Soils are typically heavy clays. The major understorey species *Carex tereticaulis* is intolerant of total immersion (at least in turbid water).

Vegetation Community	Structural Characteristics
817. Sedgy Riverine Forest/Riverine Swamp Forest Complex	Eucalypt forest to 25 metres tall with understorey dominated by larger sedges. Understorey composition indicative of at least occasional shallow flooding and a tolerance of gaps between floods of several years. Typically on heavy soils which can become wet in winter. Sedgy Riverine Forest has some floristic affinities to Red Gum Swamp. It is considered to occupy areas infrequently flooded and in which flood duration may be short, for example, higher ground surrounding the box ridges or occurring along the river levee in a position remote from the channels from which the forest first floods. These areas are therefore the last to flood and the first from which floods quickly recede. Soils are typically heavy clays. The major understorey species *Carex tereticaulis* is intolerant of total immersion (at least in turbid water).
867. Shallow Sands Woodland/Plains Woodland Mosaic	Woodland or open-forest to 15 metres tall, with a sparse shrub layer of heathy, ericoid shrubs and a species-rich ground cover dominated by grasses and annual herbs. Typically it occurs between the heavier soils of the plains and the deep-sand aeolian dunefields which overlay these plains, but also occurs on broader areas of plains covered by shallow fluvial, outwash or aeolian sands overlaying drainage-impeding clays.
869. Creekline Grassy Woodland/ Red Gum Swamp Mosaic	Grass-dominated eucalypt woodland to 15 metres tall with a range of amphibious herbs. Occurs along banks and adjacent wet flats of smaller intermittent creeks on coarse sands and stony alluvial soils and on the floodplains of larger rivers, in areas where annual rainfall is greater than 500 millimetres per annum.
873. Riverine Grassy Woodland/ Riverine Chenopod Woodland/ Wetland Mosaic	Occurs on the floodplain of major rivers, in a slightly elevated position where floods are rare, on deposited silts and sands, forming fertile alluvial soils. River red gum woodland to 20 metres tall with a groundlayer dominated by graminoids and sometimes lightly shrubby or with chenopod shrubs.
882. Shallow Sands Woodland	Woodland or open-forest to 15 metres tall, with a sparse shrub layer of heathy, ericoid shrubs and a species-rich ground cover dominated by grasses and annual herbs. Typically it occurs between the heavier soils of the plains and the deep-sand aeolian dunefields which overlay these plains, but also occurs on broader areas of plains covered by shallow fluvial, outwash or aeolian sands overlaying drainage-impeding clays.
1040. Riverine Grassy Woodland/ Riverine Swampy Woodland Mosaic	Occurs on the floodplain of major rivers, in a slightly elevated position where floods are rare, on deposited silts and sands, forming fertile alluvial soils. RIver red gum woodland to 20 metres tall with a groundlayer dominated by graminoids and sometimes lightly shrubby or with chenopod shrubs.
1050. Mosaic of Floodplain Grassy Wetland/Grassy Riverine Forest-Riverine Swamp Forest Complex	Wetland dominated by floating aquatic grasses (which persist to some extent as turf during drier periods), occurring in the most flood-prone riverine areas. Typically treeless, but sometimes with thickets of saplings or scattered more mature specimens of *Eucalyptus camaldulensis*. Occupies temporary shallow lakes in the most flood-prone riverine areas, also occurs as a narrow intermediate band around some floodway ponds.
1068. Riverine Swamp Forest/Sedgy Riverine Forest Mosaic	Open eucalypt forest to 25 metres tall with understorey dominated by obligate wetland species (or opportunistic annuals during sustained dry periods) and can range from closed sedgeland or herbland to grassy-herbaceous or extremely sparse and with cover primarily leaf-litter, black water or exposed alluvium. Occupies low-lying areas subject to reasonably regular flooding, typically flood-prone lower river terraces and low-lying areas adjacent to floodways through or within riverine forest.

12. Appendix 2: Spare channel capacity

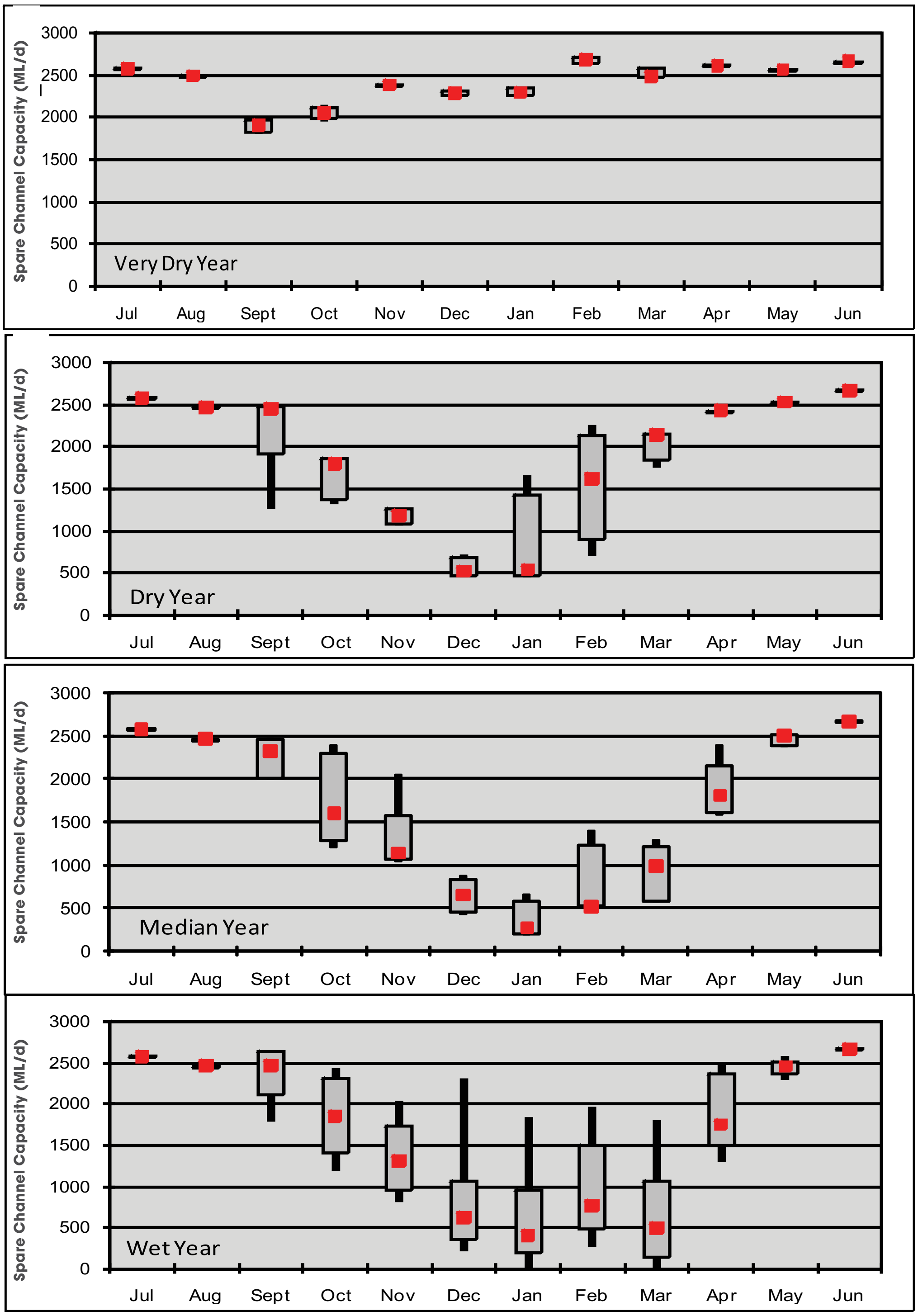


Figure 15: Spare channel capacity in the East Goulburn Main offtake, 1891–2009.

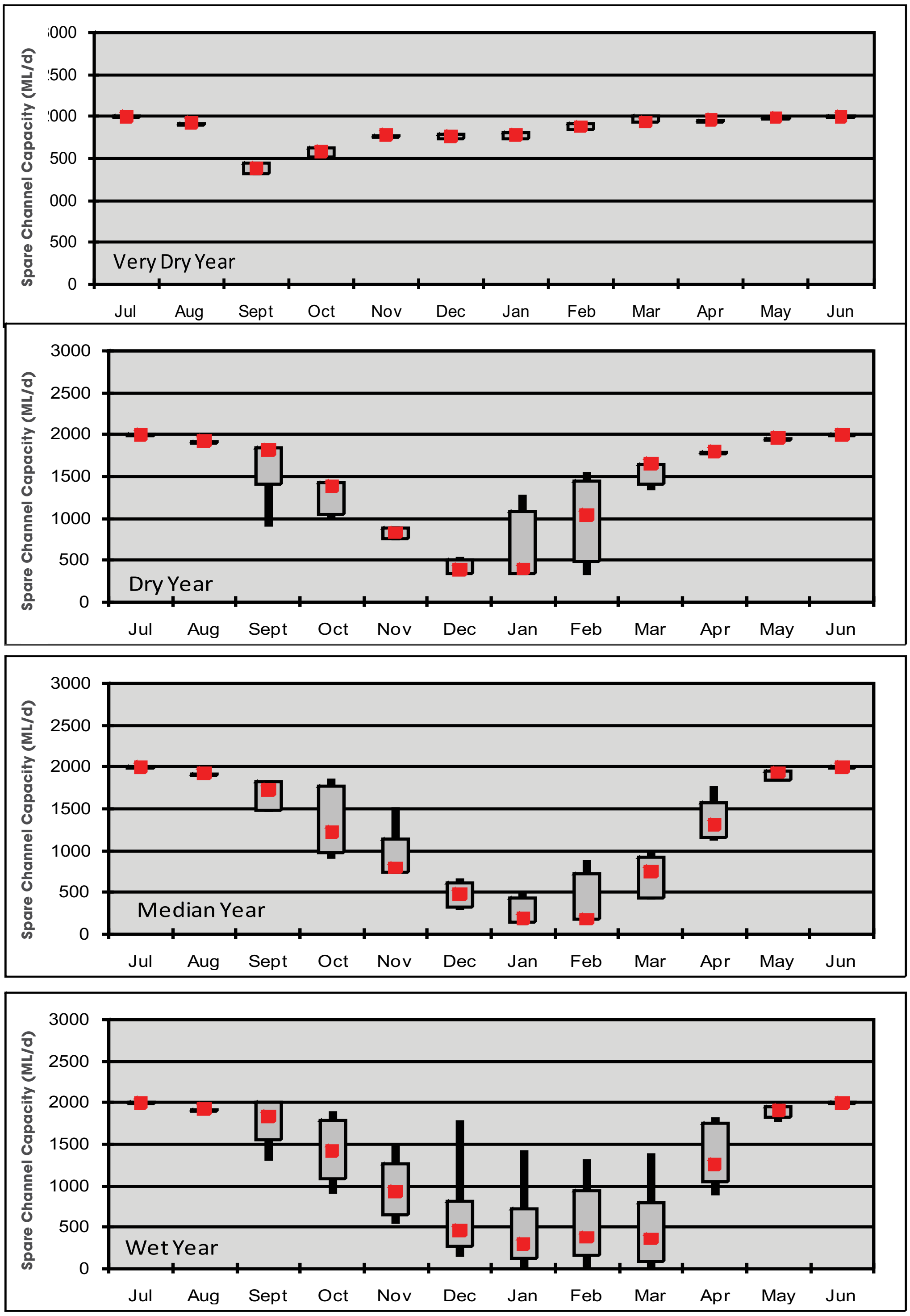


Figure 16: Spare channel capacity in the East Goulburn Main Syphon, 1891–2009.

13. Appendix 3: Operational Monitoring Report

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 two 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.

14. Appendix 4: Risk assessment framework

Risk likelihood rating

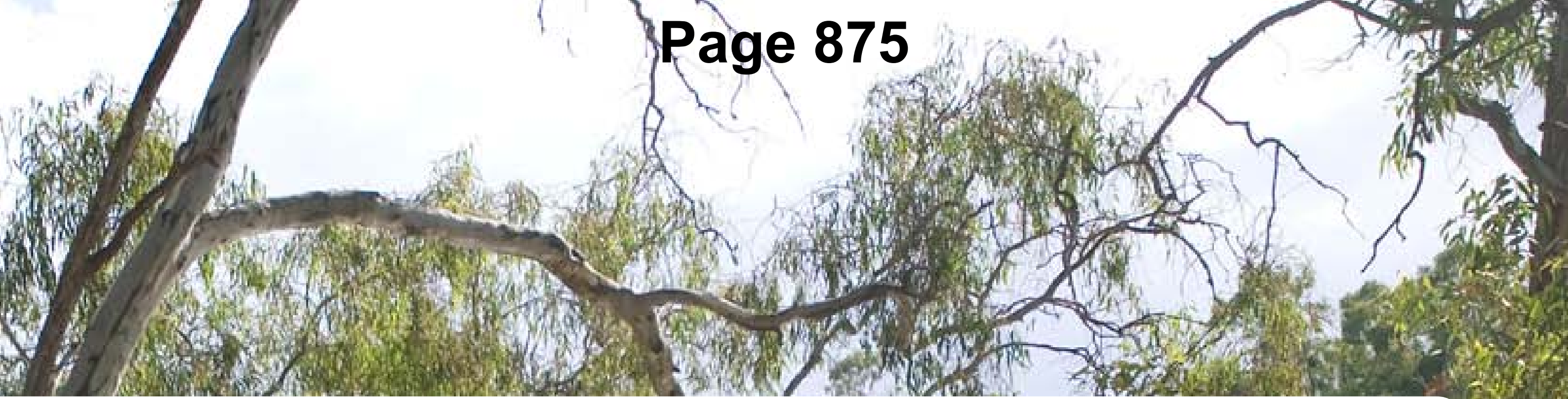
Almost certain	Is expected to occur in most circumstances
Likely	Will probably occur in most circumstances
Possible	Could occur at some time
Unlikely	Not expected to occur
Rare	May occur in exceptional circumstances only

Risk consequence rating

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

Risk analysis matrix

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



Australian Government
Commonwealth Environmental Water

ENVIRONMENTAL WATER DELIVERY

Lower Goulburn River

OCTOBER 2011 V1.0

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Peter Cottingham & Associates and SKM (2011). *Environmental Water Delivery: Lower Goulburn River.* Prepared for Commonwealth Environmental Water, Department of Sustainability, Environment, Water, Population and Communities, Canberra.

ISBN: 978-1-921733-24-6

SEWPaC acknowledges the following individuals and organisations that have been consulted in the preparation of this document:

Michael Jensz (Department of Sustainability and Environment, Victoria)
Mark Bailey (Goulburn-Murray Water)
Andrew Shields (Goulburn-Murray Water)
Geoff Earl (Goulburn Broken Catchment Management Authority)
Garry Smith (DG Consulting)
Leon Tepper (Thiess Services, Tatura)
Ben Gawne (Murray-Darling Freshwater Research Centre)
Daren Barma (Barma Water Resources)
Murray-Darling Basin Authority

Published by the Commonwealth Environmental Water Holder for the Australian Government.

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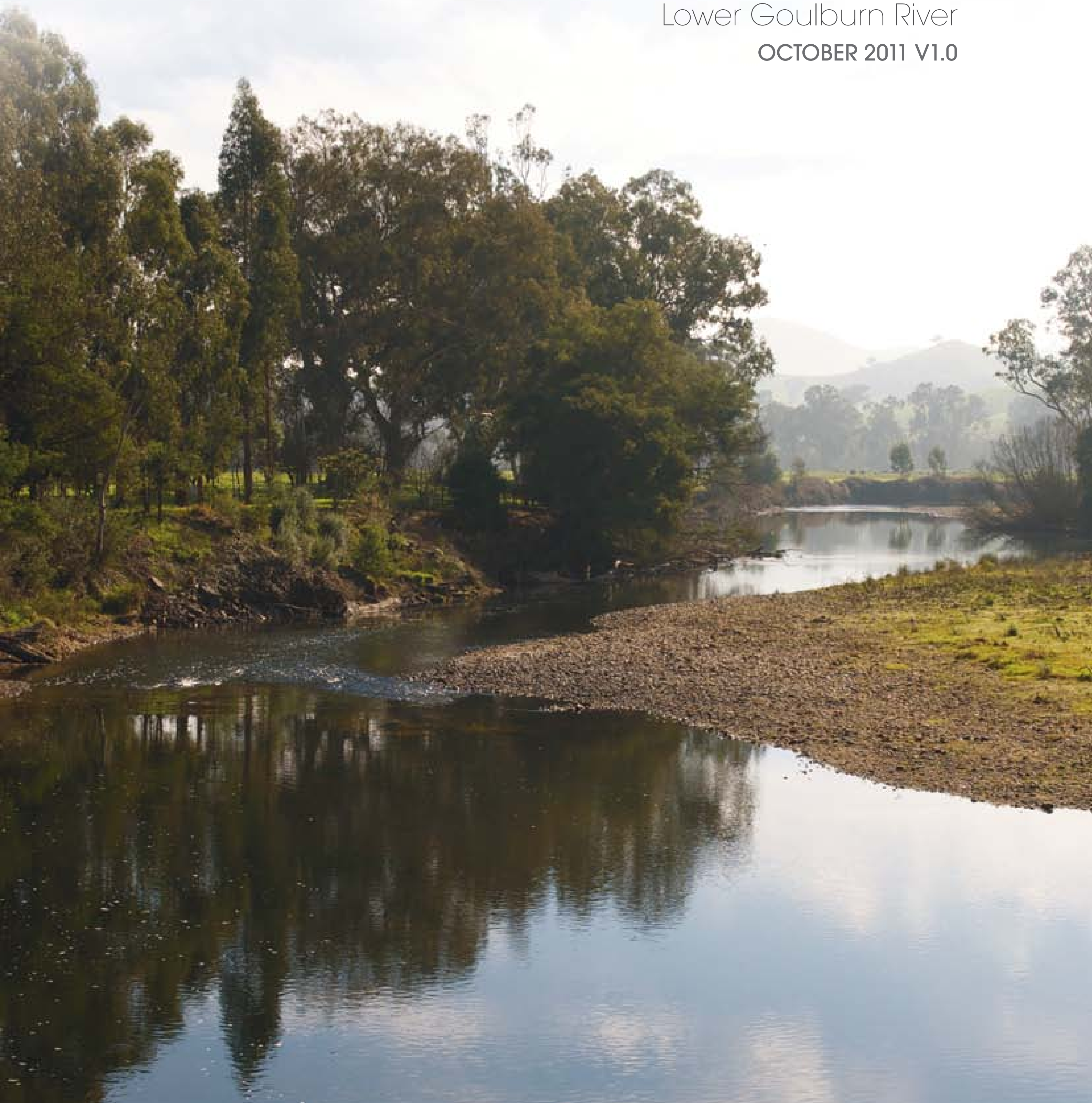

Environmental Water Delivery: Lower Goulburn River

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 Lower Goulburn River.

The Lower Goulburn River supports a number of important ecological values which have been recognised at national, regional and local scales. Ecological values include the presence of a number of threatened species of flora and fauna, intact native fish populations and areas of healthy riparian vegetation. Potential water use options for the Lower Goulburn River include the provision of baseflows for Reaches 4 and 5 as well as the provision of flow freshes in winter-spring and summer-autumn. This is expected to enable growth, reproduction and small-scale recruitment for a range of flora and fauna, including native fish.

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, Goulburn-Murray Water, Goulburn Broken 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
ARI	Average recurrence interval
BE	Bulk Entitlement
CEWH	Commonwealth Environmental Water Holder
COAG	Council of Australian Governments
DO	Dissolved oxygen
DPI	Victorian Department of Primary Industries
DSE	Victorian Department of Sustainability and Environment
EVC	Ecological vegetation classes
eWater CRC	eWater Cooperative Research Centre
FSL	Full Supply Level
GBCL	Goulburn-Broken-Campaspe-Loddon
GB CMA	Goulburn Broken Catchment Management Authority
G-MW	Goulburn-Murray Water
GSM	Goulburn Simulation Model
ISC	In Stream Condition
MDBA	Murray-Darling Basin Authority
NERWMP	North East Regional Water Monitoring Partnership
NRSWS	Northern Region Sustainable Water Strategy
NVIRP	Northern Victorian Irrigation Renewal Project
QOR	Qualification of Rights
SEWPaC	Australian Government Department of Sustainability, Environment, Water, Population and Communities
SKM	Sinclair Knight Merz
SRA	Sustainable Rivers Audit
TLM	The Living Murray program
VEFMAP	Victorian Environmental Flows Monitoring and Assessment Program
VEWH	Victorian Environmental Water Holder
VWQMN	Victorian Water Quality Monitoring Network

PART 1:
Management Aims

1. Overview

1.1 Scope and purpose of this document

Information provided in this document is intended to help establish an operational framework that provides scalable strategies for environmental water use based on the watering needs of selected assets. This document outlines the processes and mechanisms that will enable water use strategies to be implemented in the context of river operations and delivery arrangements, water trading and governance, constraints and opportunities. It specifically targets large scale water use options for the application of 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.

Information provided focuses on the environmental watering objectives and water use strategy for the Lower Goulburn River in northern Victoria, including options for the use of water held in Goulburn storages.

As part of this project, assets and potential watering options have been 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 options have been developed for each asset to meet watering objectives under a range of volume scenarios. Efforts are also made to optimise the use of environmental water to maximise environmental outcomes at multiple assets, where possible.
3. Processes and mechanisms required to operationalise environmental water delivery have been documented and include:
   - delivery arrangements and operating procedures
   - water delivery accounting methods (in consultation with operating authorities) 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.

1.2 Catchment and river system overview

The Goulburn River extends from the northern slopes of the Great Dividing Range north to the Murray River near Echuca. It has a mean annual discharge for the catchment of approximately 3,200,000 ML (CSIRO 2008), 50 per cent of which on average is diverted for use. The two major water regulation structures on the river are Lake Eildon and Goulburn Weir. The mid sections of the Goulburn River between Lake Eildon and Shepparton have a confined floodplain (up to four kilometres wide). Constructed levees confine the floodplain along the Lower Goulburn River below Shepparton. Flood water leaving the channel of the Lower Goulburn River downstream of Shepparton either returns to the channel (where blocked by levees), or flows north via the Deep Creek system that discharges to the Murray River downstream of Barmah. The Broken River is a major tributary of the Goulburn River, discharging at Shepparton.

Lake Eildon has a capacity of approximately 3,334,000 ML, and provides water to the majority of the Shepparton, Central Goulburn, Rochester and Pyramid/Boort irrigation areas (some volumes are also contributed by the Loddon and Campaspe Rivers). Water is diverted at Goulburn Weir (located eight kilometres north of Nagambie) into the East Goulburn Main Channel and is harvested into Waranga Basin (capacity 432,000 ML) via the Stuart Murray Canal and Cattanach Canal.

The storage and release of water in Lake Eildon has significantly altered the hydrology of the Goulburn River. Filling in winter to spring and releases to meet irrigation and consumptive demand mean that high flows in the mid Goulburn River channel now occur in summer to autumn, while low flows occur in winter to spring due to harvesting in Lake Eildon. Below Lake Eildon flows increase progressively due to tributary inflows. The natural seasonal flow pattern is retained below Goulburn Weir (where water is diverted to meet irrigation and consumptive demand), but is substantially reduced in volume from natural conditions. The recent decommissioning (2009-10) of Lake Mokoan means that additional water is likely to enter the Goulburn River from the Broken River during winter to spring. This is expected to bolster the natural pattern of higher flows in winter to spring and lower flows in summer to autumn in the Lower Goulburn River.

The Lower Goulburn River is a high value wetland system. The floodplain consists of a large area of habitat for fauna such as waterbirds and fish. It has a wide variety of wetland types and vegetation types, and is an excellent example of a major floodplain system.

Environmental flow recommendations have been developed for the Goulburn River (Cottingham et al. 2003, 2007), based on five representative reaches of the river (Figure 1). The information and recommendations contained in this document are based on the environmental watering needs of the Lower Goulburn River, being Reach 4 (Goulburn Weir to Shepparton) and Reach 5 (Shepparton to the Murray River) (Cottingham et al. 2003, 2007).

1.3 Overview of river operating environment

Regulation of flows along the Goulburn River downstream of Lake Eildon is managed by Goulburn-Murray Water (G-MW). Water sources for the regulated section of the Goulburn River comprise releases from Lake Eildon and tributary inflows. Flows reaching Goulburn Weir are diverted to the East Goulburn Main Channel and to Waranga Basin (via the Stuart Murray Canal and the Cattanach Canal) to meet irrigation, stock and domestic, and urban demand. Water is also released from Goulburn Weir to the Lower Goulburn River. Downstream of Goulburn Weir, the river collects tributary inflows (including the Broken River) and irrigation drain inflows prior to discharging to the Murray River near Echuca.

The region's regulated surface water resources are covered by bulk entitlements for water allocation from the Broken River and the Goulburn River and its tributaries for all urban water use. There are private diverter licences in unregulated parts of the catchment.

In 2005-06 there was 1,958,600 ML of bulk entitlement and 28,900 ML of licensed private diversion (CSIRO 2008). The Murray-Darling Basin cap on surface water diversions is set at 2,034,000 ML for the combined Goulburn, Broken and Loddon systems (CSIRO 2008). The environmental water reserve for the Goulburn Basin includes 124,600 ML held by the Victorian Environmental Water Holder (VEWH), and passing flows released as a condition of consumptive bulk entitlements held by G-MW. However, most of the environmental entitlement volume is not for the Goulburn River but for the Murray and Snowy Rivers.

Goulburn Valley Water and North East Water are responsible for the urban water supply in the Goulburn-Broken region. Coliban Water also diverts water from the Waranga Western Channel for urban water supply. G-MW is responsible for the supply of bulk raw water in the regulated river systems to these urban water corporations and manages the delivery of the raw water through the channel system. G-MW is also responsible for managing groundwater and unregulated surface water licensed diversions from the Goulburn-Broken catchment. G-MW operates Lake Eildon, Goulburn Weir, Waranga Basin and Greens Lake as part of the Goulburn River system and Lake Nillahcootie on the Broken River.

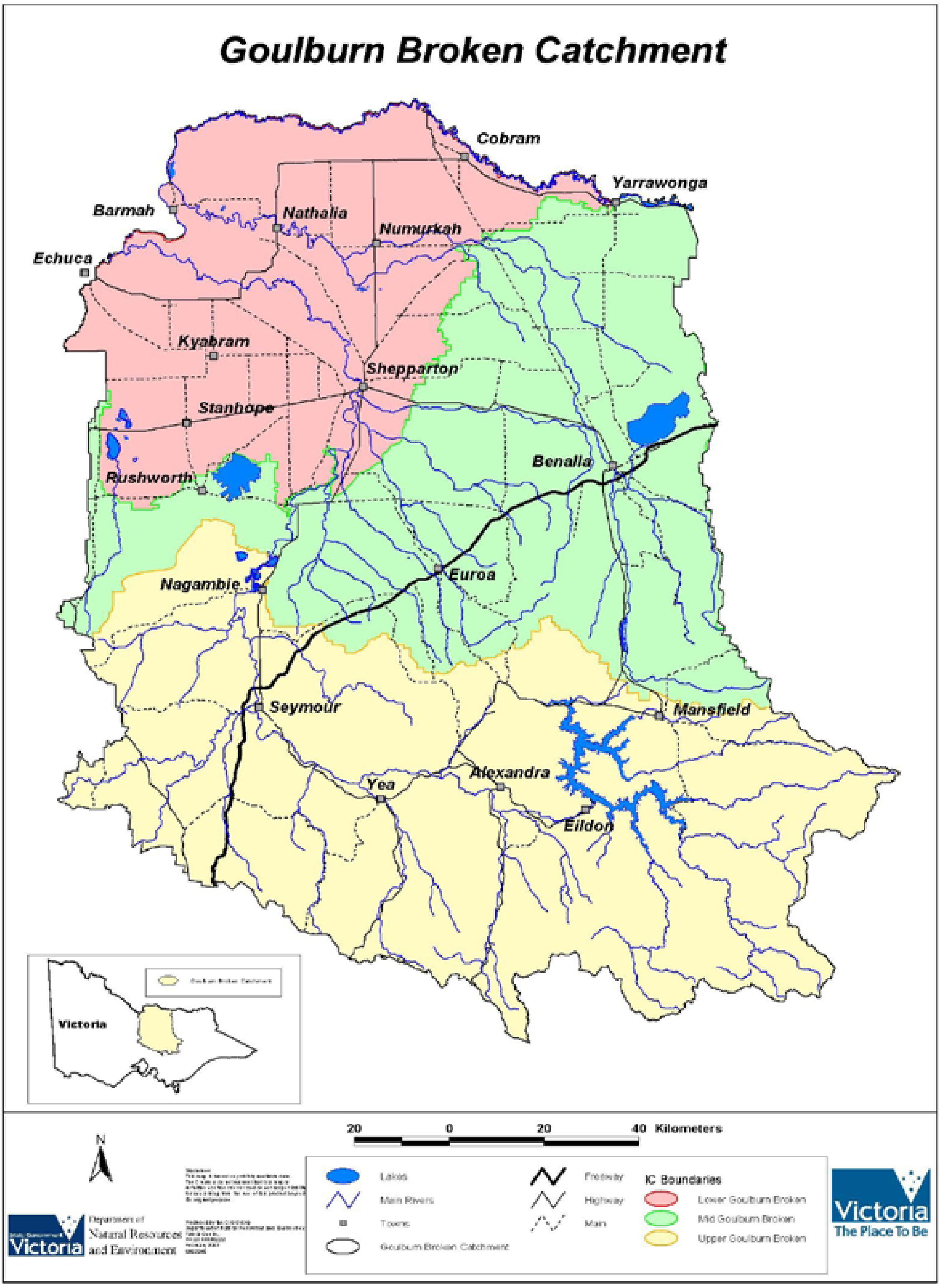

Figure 1: Map of the Goulburn catchment including the 5 reaches of the Goulburn River below Lake Eildon (courtesy DSE).

Environmental water is managed by the Goulburn Broken Catchment Management Authority (GB CMA), in cooperation with G-MW, the Victorian Department of Sustainability and Environment (DSE) and the VEWH. The Goulburn water quality reserve is managed by G-MW.

Environmental flow recommendations have been developed for the five river reaches below Lake Eildon (Cottingham et al. 2003, 2007). This document focuses on the two reaches below Goulburn Weir (Reach 4 and Reach 5), considered in previous environmental flow projects:

- Reach 4: Goulburn River from Goulburn Weir to Shepparton.
- Reach 5: Goulburn River from Shepparton to the Murray River.

Reaches 1-3, which include the Goulburn River from Lake Eildon to Goulburn Weir, were not considered in this project as there is limited scope for the use of environmental water. This is due to irrigation demand, which has resulted in an altered seasonality of flows, rather than a reduction in overall flow volume.

2. Ecological values, processes and objectives

2.1 Summary of ecosystem values for Reach 4 and Reach 5

Ecosystem values associated with the Lower Goulburn River include:

- The presence of intact native fish populations, including species such as Murray cod and golden perch.
- The intact and generally healthy riparian and floodplain areas, including river red gum communities and other ecological vegetation classes and complexes.
- The presence of threatened flora and fauna species (see Appendix 1).
- Its connection with other important rivers and floodplain systems along the Murray River, providing habitat diversity and connection at landscape scales.
- The presence of a number of Ecological Vegetation Classes (EVCs) in the Murray Fans bioregion, including Riverine Grassy Woodland, Sedgy Riverine Forest and Floodplain Riparian Woodland, as well as protecting areas of endangered Plains Woodland and Riverine Chenopod Woodland along the Murray River.
- The presence of a diversity of habitats including permanent and temporary wetlands found within the floodplain (including billabongs, sloughs, marginal swamps, potholes, scroll swales, anabranches and cut-off loops), and key wetlands such as the Gemmills Swamp nature conservation reserve and Reedy Swamp state wildlife reserve and Loch Garry Wildlife Management Cooperative Area.

Ecological values associated with the Lower Goulburn River are recognised by:

- Its listing under the Directory of Important Wetlands in Australia as an wetland of national importance.
- Its status as a National Park (forests between Echuca and Shepparton).
- Its declaration as a Heritage River.

In addition to its own intrinsic values, the Lower Goulburn River is important at a regional scale, complementing the ecosystem values recognised at nearby assets such as the Barmah-Millewa Forest and Gunbower Forest. Water from the Goulburn River discharges to the Murray River upstream of Gunbower Forest and contributes to the watering of this important Ramsar-listed site. The Lower Goulburn River also meets a number of criteria applied by the Murray-Darling Basin

Authority (MDBA 2010) in selecting hydrologic indicator sites (Table 1), which are recognised as key environmental assets across the Murray-Darling Basin.

Table 1: MDBA key environmental asset criteria met by the Lower Goulburn River floodplain (MDBA 2010).

Criterion	Description	Values
1	The asset is recognised in and/or is capable of supporting species listed in, international agreements.	The Lower Goulburn River floodplain is formally recognised in, or is capable of supporting species listed in the Japan-Australia Migratory Bird Agreement (JAMBA), the China-Australia Migratory Bird Agreement (CAMBA) or the Republic of Korea-Australia Migratory Bird Agreement (ROKAMBA). For a full list of species listed under Commonwealth legislation that have been recorded at the Lower Goulburn River Floodplain refer to Appendix 3.
3	The asset provides vital habitat.	The Lower Goulburn River Floodplain's ecological features make it a high-value wetland system. The floodplain consists of a large area of habitat for fauna such as waterbirds and fish (Department of the Environment, Water, Heritage and the Arts 2009h).
4	The asset supports Commonwealth-, state-, or territory-listed threatened species and/or ecological communities.	The Lower Goulburn River Floodplain meets this criterion because it supports species listed as threatened under Commonwealth or state legislation. For a full list of species that have been recorded refer to Appendix 3.

2.2 Broad-scale ecosystem objectives

The *Goulburn Broken Regional River Health Strategy 2005-2015* (GB CMA 2005) aims to achieve four main objectives:

1. Enhance and protect the rivers that are of highest community value from any decline in condition.
2. Maintain the condition of ecologically healthy rivers (as defined in the Victorian River Health Strategy).
3. Achieve an 'overall improvement' in the environmental condition of the remainder of rivers.
4. Prevent damage from inappropriate development and activities.

Additional ecosystem objectives have also been proposed by the MDBA (2010), and are outlined in Table 2.

Table 2: Proposed objectives and targets for the Lower Goulburn River Floodplain hydrologic indicator site (MDBA 2010).

Objectives	Justification of targets	Target
1. To protect and restore water-dependent ecosystems that support migratory birds listed in international agreements. (Criteria 1). 2. To protect and restore water-dependent ecosystems that provide vital habitat. (Criteria 3). 3. To protect and restore water-dependent ecosystems that support Commonwealth-, state- or territory-listed threatened species and/or ecological communities.	As for Barmah–Millewa Forest and Gunbower–Koondrook–Perricoota Forest, any decrease in the current area of wetlands would signal a change in ecological character.	Maintain 100% of current extent of wetlands in good condition.
Objectives 1 to 3	As for Barmah–Millewa Forest and Gunbower–Koondrook–Perricoota Forest, any change in the current area or health of vegetation communities would signal a change in ecological character.	Maintain 100% of current extent of red gum forest in good condition. Maintain 100% of current extent of red gum woodland in good condition.
Objectives 1 to 3	As for Barmah–Millewa Forest and Gunbower–Koondrook–Perricoota Forest, any reduction in the recorded frequency and abundance of bird breeding or number of bird species would signal a change in ecological character. Interim ecological objective under The Living Murray program.	Provide conditions conducive to successful breeding of waterbirds.

More specific ecosystem objectives for the Lower Goulburn River, consistent with the general objectives stated for the *Goulburn Broken Regional River Health Strategy 2005-2015* (GB CMA 2005) and those proposed by the MDBA (2010), have been used when developing environmental flow recommendations (Cottingham et al. 2003) to meet the needs of vegetation, macroinvertebrates and native fish.

Objectives relating to aquatic and riparian vegetation are to:

- enhance the extent and diversity of aquatic vegetation (in-channel and wetlands)
- contribute to processes such as river productivity
- maintain diversity of river bank vegetation
- reduce the extent and impact of weeds
- maintain continuity and cover of river bank vegetation
- enhance the extent and diversity of aquatic vegetation.

Objectives relating to macroinvertebrates are to:

- maintain or restore a trophic structure and diversity with a balanced representation of all functional groups
- achieve an Ausrivas O/E scores = Band A
- maintain or restore biomass to equivalent level of rivers elsewhere (e.g. Ovens)
- maintain dynamic, diverse food webs that support higher organisms and contribute to river health.

Objectives relating to native fish are to provide:

- suitable in-channel habitat for all life stages
- suitable off-channel habitat for all life stages
- passage for all life stages
- cues for adult migration during spawning season
- access to floodplain and off-channel habitats for spawning and/or larval rearing
- low flows for recruitment and survival
- floodplain and bench inundation for the exchange of food and organic material between the floodplain and channel.

Cottingham et al. (2007) also identified the following ecosystem objectives for geomorphology processes and in-channel primary production (phytoplankton, periphytic algae and macrophytes):

- maintain natural rates of sediment dynamics (erosion and deposition) and natural patterns of geomorphic diversity
- support dynamic, diverse food webs for phytoplankton, periphyton and macrophyte production rates, biomass levels and community composition which more closely resembles un-impacted sites.

The full list of flow-related ecosystem objectives proposed by Cottingham et al. (2007) is presented in Appendix 2.

Cottingham et al. (2003 and 2007) used the FLOWS method to assist in the identification of critical flow components, as part of the total flow regime, to protect, sustain or restore specific flow dependent assets or values. The key elements of the FLOWS process include (DNRE 2002):

- an objective setting process that links environmental objectives to flow objectives and recommendations
- the use of an environmental flows scientific panel
- the use of hydrologic and hydraulic analysis tools in the interpretation and development of recommendations.

3. Watering objectives

The 2003 study by Cottingham et al. examined how water that might be released from Lake Eildon to the Murray River as part of The Living Murray initiative could be used to protect or enhance the ecological condition of the Goulburn River. At that time, the study could only make limited assessments of future water delivery scenarios, as there was no information on the volume and timing of water that might be required for the Murray River. There was also only very limited information from which to develop recommendations for watering floodplain areas, and these were limited to recommendations for the reach immediately below Lake Eildon.

After 2003, the expansion of water markets led to increased inter-valley transfers (IVTs) and the possibility of significant use of IVTs in the Lower Goulburn River, particularly between January and March (Cottingham et al. 2007). The scientific panel that developed environmental flow recommendations in 2003 was reconvened in 2007 to consider the implications of summer IVTs for the Lower Goulburn River. This subsequent study was somewhat restricted in scope as it focused on in-channel IVTs and did not include specific flow-related ecosystem objectives for the floodplain and wetlands. However, some overbank flows were recommended based on in-channel and riparian process objectives.

Overall, the overbank recommendations in 2003 and 2007 were developed on a hydrological basis, rather than to specifically meet defined floodplain ecosystem objectives and the riverine objectives influenced by floodplain ecosystems and hydraulics. To fill this gap, DSE completed a study that specifically examined the water requirements of the Lower Goulburn River floodplain (DSE 2011). The study was based on floodplain assets, such as ecological vegetation classes (EVCs) and wetlands, along Reaches 4 and 5 of the Goulburn River. The study concluded that flow events of between 25,000 – 40,000 ML/d (7 years in 10) would maintain or improve the condition of floodplain assets.

3.1 Asset watering objectives

A detailed assessment of ecosystem objectives and their flow requirements was provided by Cottingham et al. (2007) when considering summer inter-valley transfers along the Lower Goulburn River. This study identified a range of flows that would be required to meet objectives and also accounted for inter-annual variability that would be expected under different climatic conditions. A suite of watering options for Reaches 4 and 5 of the Goulburn River are presented in Appendix 2. The 10^{th} percentile, 30^{th} percentile, 50^{th} percentile and 70^{th} percentile years can be considered representative of extreme dry, dry, median and wet years, respectively. This work, along with the floodplain recommendations of DSE (2011), provides the basis for the potential watering options in Table 3, which might be pursued under a range of climatic scenarios.

Table 3 is based on the watering needs of Reach 4 (Goulburn Weir to Shepparton), as this reach has a greater diversity of features and habitats than Reach 5. Releases from Goulburn Weir to meet the watering needs of Reach 4, along with tributary inflows, will also often meet the watering needs of Reach 5. In addition, supplementary releases over and above that required for Reach 4 can be made to meet the needs of Reach 5 based on information in Appendix 2.

It should be noted that the scenarios for extreme dry, dry, median and wet years are only indicative of what might occur during a watering year. Such categorisations infer that a particular year remains constant (i.e. a dry year remains dry) and independent from other scenarios. In reality, climatic and flow conditions can vary seasonally and annually. In addition, climatic conditions are not always indicative of flow conditions and vice versa. For example, a dry spring may be followed by a wet summer, with water availability being that of a median year overall. Climatically, conditions may be dry or very dry, but because of water demand and delivery, flow conditions in a river may be that of a median or wet year.

While the Cottingham et al. (2007) work was instigated to advise on upper flow limits over the summer to autumn period of IVT releases, both it and the work of Cottingham et al. (2003) included floodplain inundation recommendations, suggesting events of between 20,000-60,000 ML/d. Subsequent investigation by the Department of Sustainability and Environment (DSE 2011) found that most of the floodplain features such as EVCs and wetlands were inundated at discharges between 25,000 - 40,000 ML/d. The feasibility of delivering such flood events, including how best to deliver or supplement flows whilst avoiding damage to private property and infrastructure, is an issue requiring further investigation.

Recent flooding (events in 2010 and early 2011) along the Goulburn River following prolonged drought has also removed the chronic need for flood events for the next two to three years, although there are ecosystem benefits with high flow events in consecutive years (e.g. establishment of floodplain and wetland seedlings set the previous year, consecutive bird breeding events). Opportunities to augment tributary inflows and deliver small flood events should be considered as they arise. Blackwater events that have occurred after inundation of the floodplain (e.g. December 2010) serve as a reminder that 'managed' flood events may be more beneficial in winter and spring, when temperatures are lower.

Recent management of the Goulburn River (2007-2010) has been adjusted according to a Qualification of Rights (QoR) (Cottingham et al. 2010). While it is unlikely that such conditions will be imposed again, they can be considered to represent an 'extreme dry' climatic scenario. The QoR specifies a minimum flow of 150 ML/d from Goulburn Weir, down from 250 ML/d under normal conditions as prescribed by the Bulk Entitlement (BE). The QoR also changes the passing flows at the McCoys Bridge gauging station, which is the most downstream gauging site on the Goulburn River, and is located slightly upstream of its confluence with the Murray River:

- For the months of November to June inclusive, a minimum average monthly flow of 250 ML/d at a daily rate of no less than 200 ML/d (previously 350 ML/d and 300 ML/d).
- For the months of July to October inclusive, a minimum average monthly flow of 150 ML/d at a daily rate of no less than 100 ML/d (previously 400 ML/d and 350 ML/d under the BE).

Flow objectives under these and similar circumstances include:

- avoid critical loss of threatened species and communities (Murray cod, golden perch)
- maintain key refuges (deep and shallow water habitat, connection between in-channel habitats)
- avoid irretrievable damage or catastrophic events (minimise low dissolved oxygen (DO) events, fish kills)
- maintain minimum base flows and water quality.

Table 3: Proposed water management objectives for Reaches 4 and 5 under specific water availability scenarios.

	Management objectives for specific water availability scenarios			
	Extreme dry	Dry	Median	Wet
	Goal: Avoid damage to key ecological assets	Goal: Ensure ecological capacity for recovery	Goal:Maintain and improve ecological health and resilience	Goal: Improve and extend healthy aquatic ecosystems
Water availability	10th percentile year	30th percentile year	50th percentile year	70th percentile year
Objectives for Reaches 4 and 5	Flow objectives include: • Avoid critical loss of threatened species and communities (Murray cod, golden perch). • Maintain key refuges (deep and shallow water habitat, connection between in-channel habitats). • Avoid irretrievable damage or catastrophic events (minimise low DO events, fish kills). • Maintain minimum baseflow and water quality, opportunistically increasing baseflow where possible.	Flow objectives under these circumstances include: • Maintain water quality. • Increase variability in baseflow. • Increase baseflow to those recommended in environmental flow studies (310-860 ML/d). • Allow winter/spring freshes derived from tributary inflows to pass along the river. • Supplement the number of winter-spring freshes (no upper limit). • Deliver a flow fresh in summer-autumn (up to 6,600 ML/d*). These flows will: • Support the survival and growth of threatened species and communities, including limited small-scale recruitment (Murray cod, golden perch). • Maintain a diversity of in-channel habitats (pools, runs, snags). • Maintain low-flow river functional processes such as planktonic and macrophyte production. • Provide some fluctuation in low flows to vary habitat availability and refresh habitat quality.	Under this scenario, there would be sufficient water available to meet BE requirements. There is also likely to be sufficient water to deliver one or more flow freshes, although this will usually depend on the frequency and magnitude of rainfall-rejection flows (i.e. cancelled irrigation orders). There will be sufficient water available to: • Enable growth, reproduction and small-scale recruitment for a diverse range of flora and fauna in the low-flow channel (e.g. native fish such as Murray cod, trout cod, golden perch). • Promote connectivity between the river channel and low-lying features such as bars and benches. • Inundate vegetation on the lower levels of the river bank. • Promote watering of riparian vegetation higher up the river bank and onto the floodplain. • Achieve bankfull discharge required to sustain geomorphological processes. • Achieve connection between the river channel and the wider floodplain support high-flow river and floodplain functional processes.	Under this scenario, objectives (over and above those for a median year) will be to: • Enable growth, reproduction and large-scale recruitment for a diverse range of riverine and floodplain/wetland flora and fauna. • Increase habitat availability by increasing winter-spring base flows, and increasing the frequency and/ or magnitude of flow freshes. • Promote watering of riparian vegetation higher up the river bank and onto the floodplain. • Achieve bankfull discharge required to sustain geomorphological processes. • Achieve connection between the river channel and the wider floodplain to support high-flow river and floodplain functional processes.

	Management objectives for specific water availability scenarios			
	Extreme dry	Dry	Median	Wet
	Goal: Avoid damage to key ecological assets	Goal: Ensure ecological capacity for recovery	Goal:Maintain and improve ecological health and resilience	Goal: Improve and extend healthy aquatic ecosystems
Water availability	10th percentile year	30th percentile year	50th percentile year	70th percentile year
Potential use of environmental water	Environmental water can be used to supplement base flows to increase variability in habitat availability, ensure connection between habitats, and help to maintain water quality. Environmental water could also be used to meet the following objectives (Cottingham et al. 2003, 2007), with priority given to supplementing flows from spring as far as possible into summer-autumn: • 310 ML/d (>80% of the time) Achieves two macroinvertebrate objectives: 1. Provision of conditions suitable for aquatic vegetation, which provides habitat for macroinvertebrates. 2. Provision of slackwater habitat favourable for planktonic production (food source) and habitat for macroinvertebrates. • 400 ML/d (>93% of the time) Achieves one macroinvertebrate and one native fish objective: 1. Submersion of snag habitat within the euphotic zone to provide habitat and food sources for macroinvertebrates. 2. Suitable in-channel habitat for all small bodied fish life stages.	Environmental water can be used to supplement base flows to increase variability in habitat availability in keeping with the objectives above (Cottingham et al. 2003, 2007), beyond those provided by the BE: • 500 ML/d (>99% of the time) Achieves one native fish objective: 1. Suitable in-channel habitat (area of slow, shallow water) for all small bodied fish life stages. • 540 ML/d (>90% of the time) Achieves two macroinvertebrate objectives: 1. Entrainment of litter packs available as food/ habitat sources for macroinvertebrates. 2. Maintenance of water quality suitable for macroinvertebrates. • 610 ML/d (>90% of the time) Achieves one native fish objective: 1. Provide deep water habitat for large-bodied native fish. • 830 ML/d (>95% of the time) Achieves one macroinvertebrate objective: 1. Submersion of snag habitat within the euphotic zone to provide habitat and food sources for macroinvertebrates.	Environmental water can be used to supplement winter-spring flows and deliver bankfull and overbank flows to meet various ecosystem objectives (Cottingham et al. 2003, 2007). The difference between this and the dry scenario is that baseflow can be maintained for longer durations, and that freshes (both in winter-spring and summer) can be more frequent or of larger magnitude. However, it should be noted that recent investigations suggest that it will be very difficult to use environmental water to supplement bankfull and overbank flows. • 500 ML/d (>98% of the time) Achieves one native fish objective: 1. Suitable in-channel habitat (area of slow, shallow water) for all small bodied fish life stages. • 540 ML/d (>99% of the time) Achieves two macroinvertebrate objectives: 1. Entrainment of litter packs available as food/ habitat sources for macroinvertebrates. 2. Maintenance of water quality suitable for macroinvertebrates.	Environmental water can be used to supplement winter-spring flows and deliver bankfull and overbank flows to meet various ecosystem objectives (Cottingham et al. 2003, 2007). The difference between this and the median year scenario is that baseflow can be maintained for longer durations, and that freshes (both in winter-spring and summer) can be more frequent or of larger magnitude and duration: • 500 ML/d (>98% of the time) Achieves one native fish objective: 1. Suitable in-channel habitat (area of slow, shallow water) for all small bodied fish life stages. • 540 ML/d (>99% of the time) Achieves two macroinvertebrate objectives: 1. Entrainment of litter packs available as food/ habitat sources for macroinvertebrates. 2. Maintenance of water quality suitable for macroinvertebrates. • 610 ML/d (>98% of the time) Achieves one native fish objective: 1. Provide deep water habitat for large-bodied native fish.

Water availability	Management objectives for specific water availability scenarios			
	Extreme dry	Dry	Median	Wet
	Goal: Avoid damage to key ecological assets	Goal: Ensure ecological capacity for recovery	Goal:Maintain and improve ecological health and resilience	Goal: Improve and extend healthy aquatic ecosystems
	10th percentile year	30th percentile year	50th percentile year	70th percentile year
	• 500 ML/d (>98% of the time) Achieves one native fish objective: 1. Suitable in-channel habitat (area of slow, shallow water) for all small bodied fish life stages. • 540 ML/d (>80% of the time) Achieves two macroinvertebrate objectives: 1. Entrainment of litter packs available as food/habitat source for macroinvertebrates. 2. Maintenance of water quality suitable for macroinvertebrates. • 610 ML/d (>80% of the time) Achieves one native fish objective: 1. Provide deep water habitat for large-bodied native fish. • Bank any excess water for subsequent years.	• 860 ML/d (>94% of the time) Achieves one geomorphology objective: 1. Maintain pool depth. • Up to 6,600 ML/d (up to 7 days)* Deliver a flow fresh in summer-autumn that would increase habitat variability for macroinvertebrates and native fish, and increase habitat quality by maintaining or improving water quality (including in pools) and mobilising fine sediment deposits. • Up to bankfull** Deliver a winter-spring flow fresh that would achieve the following objectives: 1. Improvement of macroinvertebrate and native fish habitat quality (e.g. disruption of biofilms, flushing of fine sediments). 2. Entrainment of litter packs available as food/habitat sources for macroinvertebrates. 3. Planktonic algae production rates, biomass levels and community composition more resembling un-impacted sites, promoting dynamic and diverse food webs. 4. Pre-spawning and movement cues for some native fish species (e.g. golden perch). 5. Maintain natural rates of sediment mobilisation and deposition.	• 610 ML/d (>99% of the time) Achieves one native fish objective: 1. Provide deep water habitat for large-bodied native fish. • 830 ML/d (98% of the time) Achieves one macroinvertebrate objective: 1. Submersion of snag habitat within the euphotic zone to provide habitat and food sources for macroinvertebrates. • 860 ML/d (100% of the time) Achieves one geomorphology objective: 1. Maintain pool depth. • Up to 6,600 ML/d (up to 7 days)* Deliver a flow fresh in summer-autumn that would increase habitat variability for macroinvertebrates and native fish, and increase habitat quality by maintaining or improving water quality (including in pools) and mobilising fine sediment deposits. • Up to bankfull** Deliver a winter-spring flow fresh that would achieve the following objectives:	• 830 ML/d (>98% of the time) Achieves one macroinvertebrate objective: 1. Submersion of snag habitat within the euphotic zone to provide habitat and food sources for macroinvertebrates. • 860 ML/d (100% of the time) Achieves one geomorphology objective: 1. Maintain pool depth. • Up to 6,600 ML/d(up to 7 days)* Deliver a flow fresh in summer-autumn that would increase habitat variability for macroinvertebrates and native fish, and increase habitat quality by maintaining or improving water quality (including in pools) and mobilising fine sediment deposits. • Up to bankfull** Deliver a winter-spring flow fresh that would achieve the following objectives: 1. Improvement of macroinvertebrate and native fish habitat quality (e.g. disruption of biofilms, flushing of fine sediments).

	Management objectives for specific water availability scenarios			
	Extreme dry	Dry	Median	Wet
	Goal: Avoid damage to key ecological assets	Goal: Ensure ecological capacity for recovery	Goal:Maintain and improve ecological health and resilience	Goal: Improve and extend healthy aquatic ecosystems
Water availability	10th percentile year	30th percentile year	50th percentile year	70th percentile year
		• Supplementing (piggy-backing) catchment inflows to ensure bankfull and overbank events to inundate riparian and floodplain assets (25,000 – 40,000 ML/d, minimum 4-5 days duration, 7-10 years out of 10***). • Bank any excess water for subsequent years.	1. Improvement of macroinvertebrate and native fish habitat quality (e.g. disruption of biofilms, flushing of fine sediments). 2. Entrainment of litter packs available as food/ habitat sources for macroinvertebrates. 3. Planktonic algae production rates, biomass levels and community composition more resembling un-impacted sites, promoting dynamic and diverse food webs. 4. Pre-spawning and movement cues for some native fish species (e.g. golden perch). 5. Maintain natural rates of sediment mobilisation and deposition. • Supplementing (piggy-backing) catchment inflows to ensure bankfull and overbank events to inundate riparian and floodplain assets (25,000 – 40,000 ML/d, minimum 4-5 days duration, 7-10 years out of 10***). • Banking of water to supplement catchment inflows for bankfull and overbank events in subsequent years.	2. Entrainment of litter packs available as food/habitat source for macroinvertebrates. 3. Planktonic algae production rates, biomass levels and community composition more resembling un-impacted sites, promoting dynamic and diverse food webs. 4. Pre-spawning and movement cues for some native fish species (e.g. golden perch). 5. Maintain natural rates of sediment mobilisation and deposition. • Supplementing (piggy-backing) catchment inflows to ensure bankfull and overbank events to inundate riparian and floodplain assets (25,000 – 40,000 ML/d, minimum 4-5 days duration, 7-10 years out of 10***). • Bank any excess water for subsequent years.

*An upper limit is applied to summer freshes to avoid increased rates of sediment deposition in pools. See Cottingham et al. (2007) for further explanation.

**Information on the frequency, magnitude and duration of freshes is contained in Cottingham et al. (2003).

***For further details, see DSE (2011).

PART 2:
Water Use Strategy

4. Environmental Water Requirements

4.1 Baseline flow characteristics

Current flow is less than natural flow over the non-irrigation season for all reaches of the Goulburn River downstream of Lake Eildon, because of the water being harvested in Lake Eildon during these months. In contrast, summer releases from Lake Eildon for irrigation supply mean that flows are kept unnaturally high between Lake Eildon and Goulburn Weir.

Historically, releases from Lake Eildon during the irrigation season typically peaked at around 10,000 ML/d. In recent years, drought combined with improved farming practices have reduced peak irrigation season releases, which are now in the order of 6,000 ML/d.

Prior to the introduction of inter-valley trading, most of the water released from Lake Eildon for supplying irrigation demands was diverted at Goulburn Weir. Reach 4 and Reach 5 of the Goulburn River are downstream of Goulburn Weir. Consequently, flows through Reach 4 were generally regulated to a minimum of 250 ML/d prior to 2005-06 (72 per cent of the time in the non-irrigation season and 79 per cent of the time in summer). Reach 5 was less regulated, because of the contribution of tributary inflows, such as the Broken River. The difference between the natural and current flow duration curves for Reach 4 and Reach 5 (as modelled in 2006) is shown in Figure 2 to Figure 5.

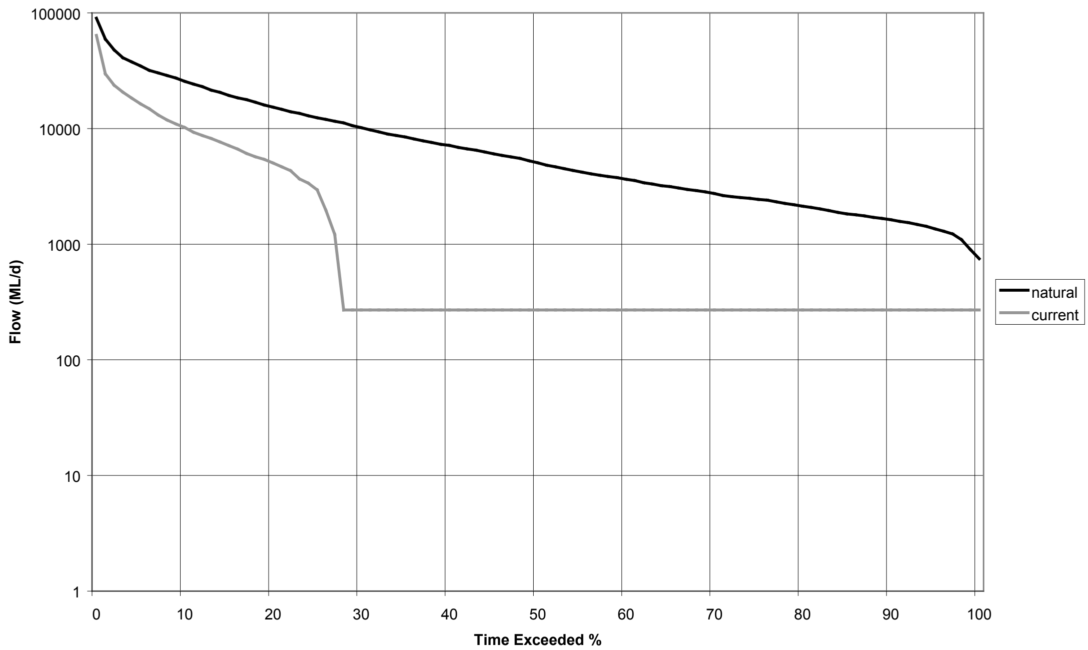

Figure 2: Flow duration curve for the non-irrigation season in the Goulburn River Reach 4, downstream of Goulburn Weir prior to 2006 (SKM 2006).

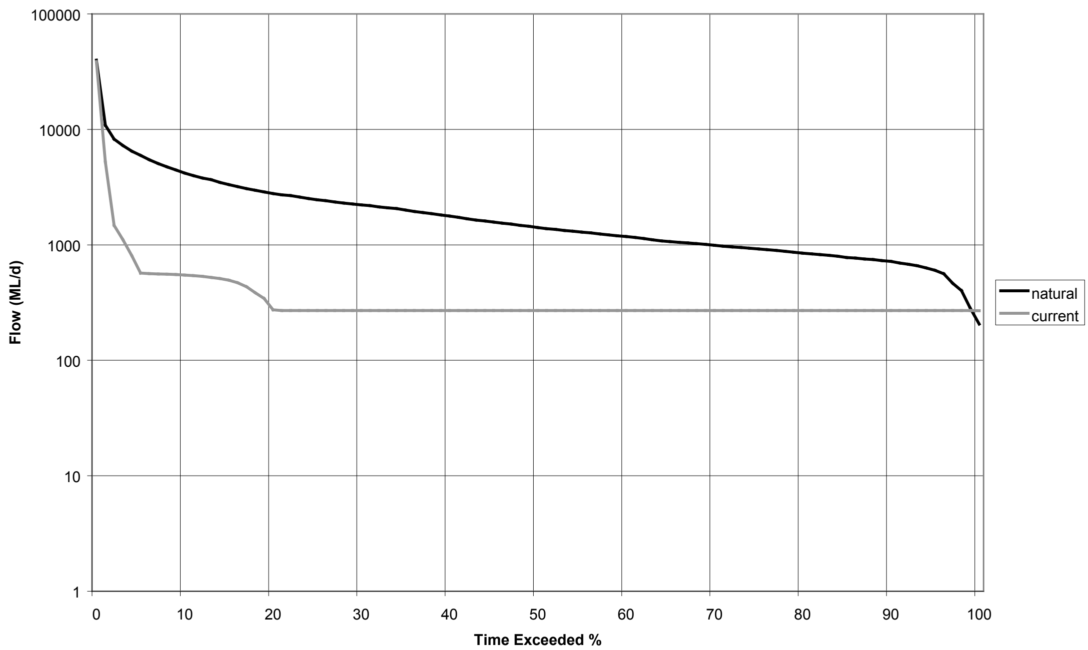

Figure 3: Flow duration curve for summer (Dec-May) in the Goulburn River Reach 4, downstream of Goulburn Weir prior to 2006 (SKM 2006).

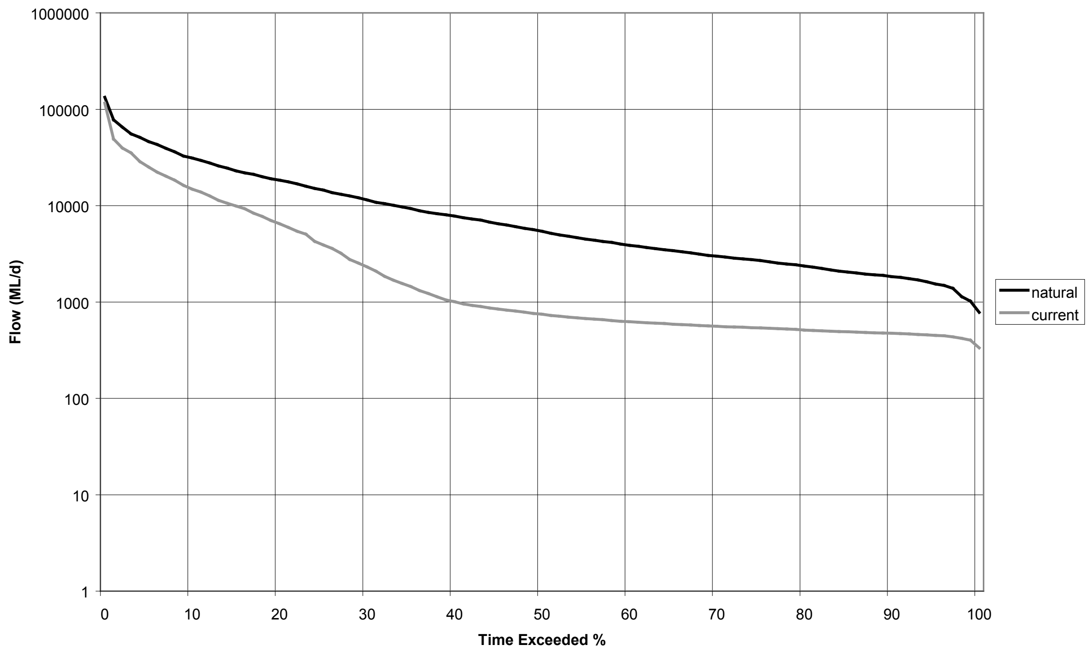

Figure 4: Flow duration curve for non-irrigation season in the Goulburn River Reach 5, Shepparton to the Murray River prior to 2006 (SKM 2006).

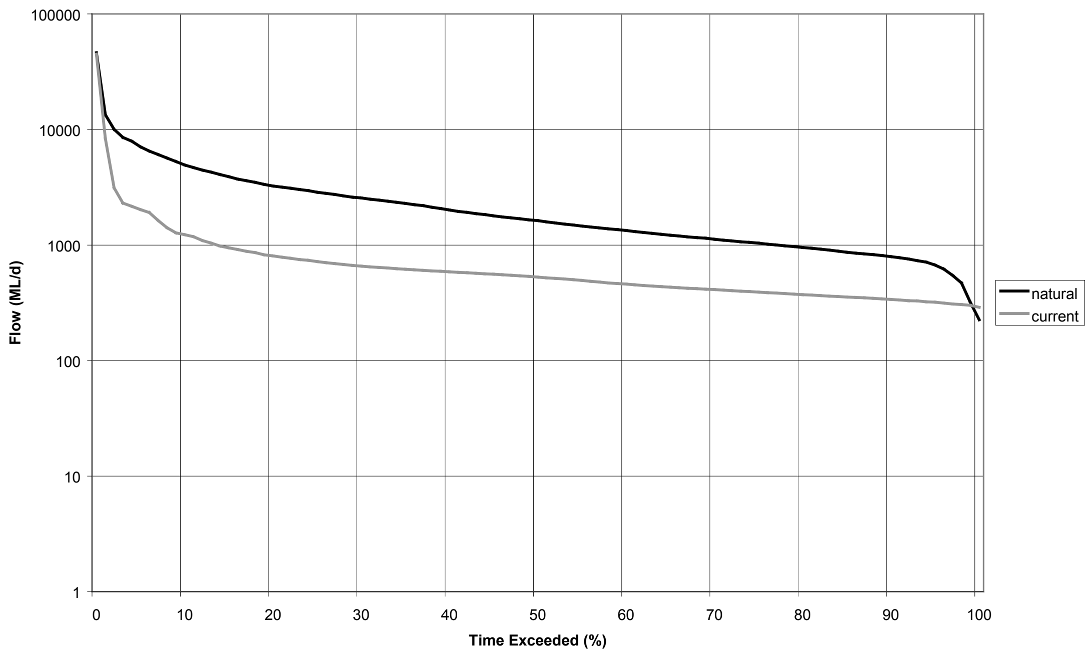

Figure 5: Flow duration curve for summer (Dec-May) in the Goulburn River Reach 5, Shepparton to the Murray River prior to 2006 (SKM 2006).

In more recent times, flows in Reach 4 and Reach 5 during the irrigation season have been increased by inter-valley transfers from Lake Eildon to the Murray River. In 2005-06, inter-valley transfers were delivered in a single period from January to March (Figure 6), but delivery in several shorter duration periods is also possible in any one year. Expectations are that water trades will result in typical inter-valley transfers of 1,000 – 2,000 ML/d, with peaks of up to 4,000 ML/d. However, short duration peaks of up to 8,000 ML/d are considered possible (Cottingham et al. 2007). Note that such transfers could only occur outside periods of significant irrigation demand (at Goulburn Weir) as there is insufficient channel capacity in the mid-Goulburn to pass 8,000 ML/d over Goulburn Weir in addition to supplying high irrigation demands.

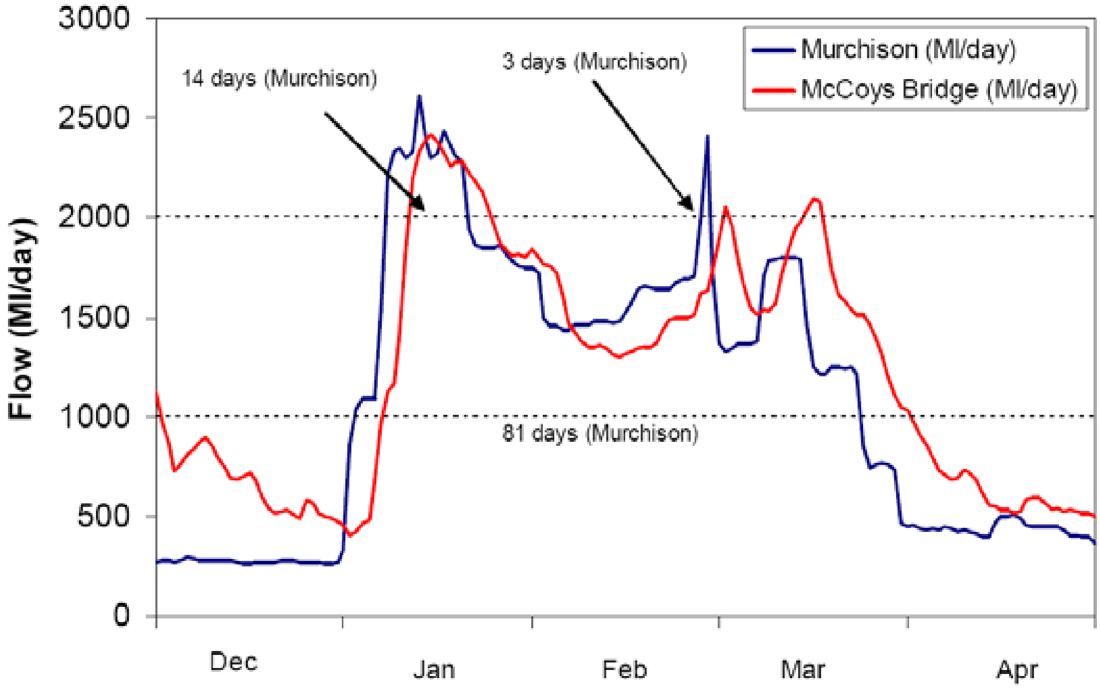

Figure 6: Pattern of flow at Murchison and McCoys Bridge during the summer and autumn of 2005-06. The duration of events above 1,000 ML/d and 2,000 ML/d are shown (Cottingham et al. 2007).

The daily flow model of the Lower Goulburn River is known as the Goulburn-Broken-Campaspe-Loddon REALM model. At the time of preparing this document, the model had not been updated for several years and many of the assumptions in the model were out of date. Hence gauged flow data has been used in the information presented below.

The period of data assessed (Table 4 and Table 5) is from 1974 to 2010. This period of record includes a range of climatic conditions, including the recent drought conditions and the wetter conditions during the 1970s. In these tables, the 30th percentile flow is the flow that is not exceeded on 30 per cent of all days in that month over the historical period (i.e. 30 per cent of July days had a flow at Shepparton below 513 ML/d over the historical period). These tables show that a minimum flow of 150-300 ML/d has historically been maintained in the Lower Goulburn River and that, in median and wet years, the streamflow in these reaches peaks in winter to spring. Note that the values in Table 4 and Table 5 are derived independently for each month. The seasonal pattern of average daily flows through Reach 4 and Reach 5 of the Goulburn River (Figure 7) are similar to the seasonal pattern of percentile flows.

A daily Source-Rivers model of the Goulburn River is currently being developed by SKM for the GB CMA and the eWater Cooperative Research Centre (eWater CRC). This model currently only includes the main stem of the river to model possible flow management during unregulated winter and spring flows, and does not include many of the complex operating rules associated with irrigation water delivery. Further development of this daily time step model will assist with the modelling of environmental flows on the Goulburn River in the future.

Table 4: Streamflow (ML/d) for the Goulburn River at Shepparton (1974-2010); Reach 4.

Month	Extreme dry year (minimum on record)	Dry year (30th percentile daily flow)	Median year (50th percentile daily flow)	Wet year (70th percentile daily flow)
Jul	190.3	513.3	747.4	3,221.9
Aug	204.3	699.5	2,433.0	8,463.2
Sep	214.9	812.0	2,661.2	9,024.6
Oct	185.1	579.6	943.0	2,165.4
Nov	282.0	491.2	665.5	1,150.8
Dec	235.4	419.5	516.1	692.4
Jan	151.9	423.0	522.2	756.6
Feb	167.5	403.0	483.0	664.0
Mar	176.1	422.6	501.9	645.5
Apr	198.4	427.8	499.8	592.2
May	214.7	410.8	492.9	698.8
Jun	274.2	493.0	670.1	1,272.5

Table 5: Streamflow (ML/d) for the Goulburn River at McCoys Bridge (1976-2010); Reach 5.

Month	Extreme dry year (minimum on record)	Dry year (30th percentile daily flow)	Median year (50th percentile daily flow)	Wet year (70th percentile daily flow)
Jul	203.5	538.0	782.2	3,454.1
Aug	195.9	726.5	2,568.0	9,639.7
Sep	186.2	921.0	3,329.0	9,444.5
Oct	232.5	675.3	1,178.5	2,558.8
Nov	304.8	570.4	807.6	1,299.9
Dec	204.0	493.0	618.7	754.1
Jan	202.8	481.8	595.0	794.9
Feb	257.9	455.0	566.9	781.0
Mar	245.2	439.0	535.0	716.9
Apr	272.0	460.6	565.8	688.0
May	327.5	483.4	607.2	825.4
Jun	291.7	475.5	659.8	1,378.0

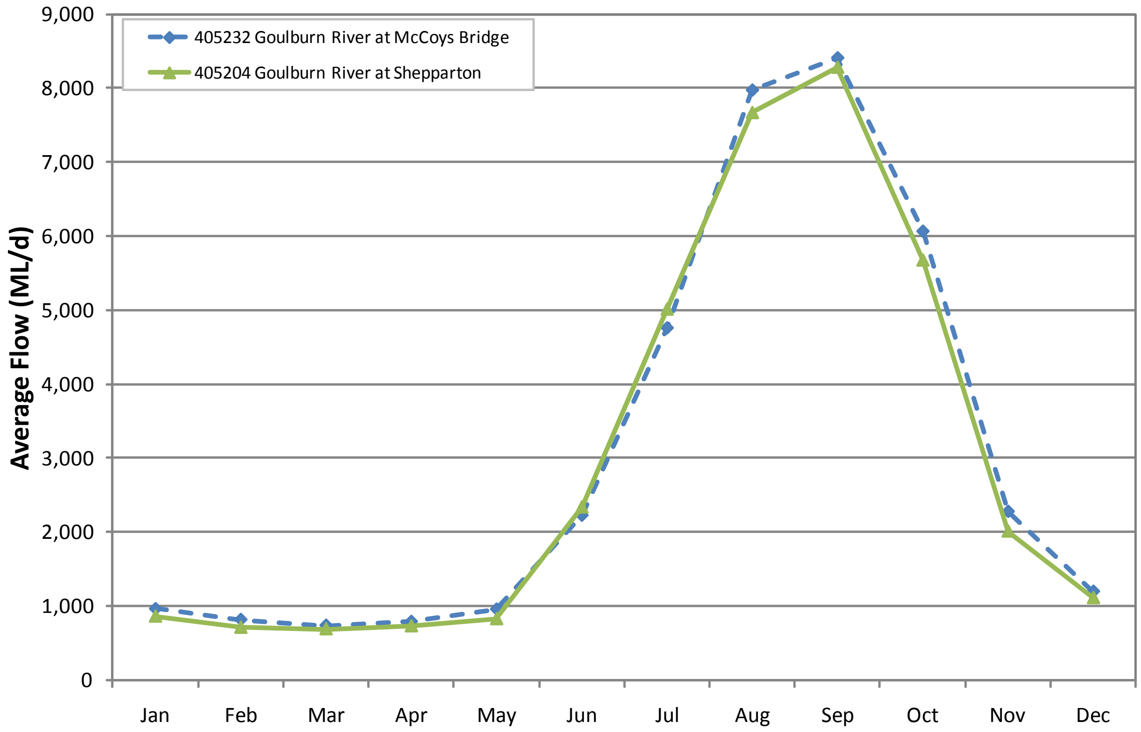

Figure 7: Average daily flow recorded at streamflow gauges at McCoys Bridge (405232) and Shepparton (405204) between 1977 and 2010.

4.2 Environmental water demands

Environmental water can be used to supplement flows to deliver the proposed flow components or events identified earlier in this document (Table 3, Section 3). Delivering these flows can increase habitat availability, ensure connection between habitats and support water quality. The actual volumes of water required will vary depending on antecedent conditions that affect inflows. The volumes identified in Table 6 and Table 7 are examples based on meeting the shortfall between a limited number of flow targets (310 ML/d, 400 ML/d, 500 ML/d, 540 ML/d, 610 ML/d, 830 ML/d or 860 ML/d) and modelled flow in Reach 4 and Reach 5 for extreme dry, dry, median and wet years.

Flows were modelled in the monthly Goulburn Simulation Model (GSM). To calculate shortfalls in meeting daily recommendations, it was assumed the monthly flow was distributed evenly across the month. The categorisation of extreme dry, dry, median and wet years was based on Goulburn system allocations, as explained further in Section 5.

Based on this information, up to 6,000 ML is required to supplement baseflow in an extreme dry year and up to 110,000 ML could be required to supplement baseflow in a wet year. This indicates that Commonwealth environmental water holdings in the Goulburn system would be sufficient to meet baseflow targets in a very dry year, but water would need to be traded into the system to meet the higher baseflow targets in dry to wet years. The monthly distribution of shortfalls for each flow threshold is contained in Appendix 3.

Historically, based on gauged flows for the Goulburn River at Shepparton (405204) and the Goulburn River at McCoys Bridge (405232), the delivery of a summer to autumn fresh of up to 6,600 ML/d has rarely been met. The only years there have been flows greater than 6,600 ML/d during summer to autumn in the Lower Goulburn River are 1975, 1984, 1986, 1988, 1989, 1992 and 2005, which were all wet years, with the exception of 2005. The summer fresh recommendation is applicable to dry, median and wet years.

Table 6: Additional annual volumes (GL) required to meet baseflow targets related to ecosystem objectives for Reach 4 of the Lower Goulburn River.

Baseflow	310 ML/d		400 ML/d		500 ML/d		540 ML/d		610 ML/d		830 ML/d		860 ML/d	
Modelled shortfall in meeting baseflow target year-round (GL)														
Year	**Min**	**Max**	**Min**	**Max**	**Min**	**Max**	**Min**	**Max**	**Min**	**Max**	**Min**	**Max**	**Min**	**Max**
Very Dry	0.0	0.0	2.9	5.8	n/a	n/a	n/a	n/a	34.2	54.3	n/a	n/a	n/a	n/a
Dry	n/a	n/a	n/a	n/a	0.0	15.8	0.0	20.6	0.0	30.9	1.2	65.1	2.0	70.5
Median	n/a	n/a	n/a	n/a	0.0	19.2	0.0	25.3	0.0	38.7	0.0	85.1	0.0	91.5
Wet	n/a	n/a	n/a	n/a	0.0	21.0	0.0	28.8	0.0	43.6	0.0	102.6	0.0	110.8

Table 7: Additional annual volumes (GL) required to meet baseflow targets related to ecosystem objectives for Reach 5 of the Lower Goulburn River.

Baseflow	310 ML/d		400 ML/d		500 ML/d		540 ML/d		610 ML/d		830 ML/d		860 ML/d	
Modelled shortfall in meeting baseflow target year-round (GL)														
Year	**Min**	**Max**	**Min**	**Max**	**Min**	**Max**	**Min**	**Max**	**Min**	**Max**	**Min**	**Max**	**Min**	**Max**
Very Dry	0.0	0.0	0.8	3.1	n/a	n/a	n/a	n/a	28.3	40.3	n/a	n/a	n/a	n/a
Dry	n/a	n/a	n/a	n/a	0.0	9.2	0.0	14.0	0.0	22.4	0.0	59.5	0.0	64.9
Median	n/a	n/a	n/a	n/a	0.0	9.4	0.0	13.2	0.0	22.1	0.0	68.2	0.0	74.5
Wet	n/a	n/a	n/a	n/a	0.0	16.6	0.0	25.0	0.0	41.9	0.0	98.5	0.0	106.7

Table 8 shows that if a fresh is delivered solely from environmental water releases (i.e. without any natural inflow contributions downstream of Lake Eildon), the volume of water required above baseflow to deliver a peak flow of up to 6,600 ML/d ranges from 38,000 ML to 46,000 ML.

Table 8: The additional volume of water required to deliver a fresh of 6,600 ML/d to the Lower Goulburn River above varying baseflows.

Baseflow	Additional water required to deliver fresh of 6,600 ML/d above baseflow volume* (GL)
500 ML/d	45.9
540 ML/d	44.9
610 ML/d	43.3
830 ML/d	38.7
860 ML/d	38.1

Note:Assumes a rate of rise of 1.35 and a rate of fall of 0.85 from recorded baseflow either side of the event.

Table 9 shows the volume of water required above the hydrographs recorded at Shepparton (405204) and McCoys Bridge (405232) that would be needed to reach a threshold of 6,600 ML/d in the Lower Goulburn for some select summer to autumn rainfall-runoff events. Required event volumes for similar recorded flood peaks can vary according to the pattern of flow either side of the recorded flood peak.

Table 9: The additional volume of water required in Reach 4 to deliver a fresh of 6,600 ML/d to the Lower Goulburn River above recorded peaks.

Event	Recorded peak	Additional water required to deliver fresh of 6,600 ML/d*
February 1987	1810 ML/d	45 GL
March 1988	2605 ML/d	29 GL
March 2010	3365 ML/d	32 GL
January 2008	5000 ML/d	18 GL

Note:Assumes a rate of rise of 1.35 and a rate of fall of 0.85 from the recorded baseflow either side of the event.

Proposals have also been made for winter to spring bankfull events of up to 19,000 ML/d and overbank events of 25,000 to 40,000 ML/d (DSE 2011). Based on recorded flow for Shepparton (405204), winter to spring flows above 19,000 ML/d have been recorded in 20 years since 1974 (5.6 years in 10). Over this period, flows greater than 25,000 ML/d have been recorded in 17 years (4.7 years in 10) while flows greater than 40,000 ML/d have been recorded in 8 years (2.2 years in 10). Bankfull events can be considered in all dry, median and wet years. Overbank events are proposed in 7 out of 10 dry, median and wet years. This is greater than the observed frequency of overbank flows recorded historically since 1974.

Table 10 shows the volume required downstream of Goulburn Weir to enhance and extend historical flow peaks to the desired bankfull and overbank peak flow and duration. Up to 140,000 ML would have been required in Reach 4 for the bankfull flow event, whilst up to 420,000 ML would have been required in Reach 4 for the overbank events. Required event volumes for similar recorded flood peaks can vary according to the pattern of flow either side of the recorded flow peak.

Table 10: The additional volume of water required in Reach 4 to deliver a bankfull event of 19,000 ML/d or overbank events of 25-40,000 ML/d to the Lower Goulburn River above recorded peaks.

Event	Recorded peak (ML/d)	Additional water required to deliver event (GL)*		
		Bankfull Flow of 19,000 ML/d	Overbank Flow of 25,000 ML/d	Overbank Flow of 40,000 ML/d
Sep 1998	20,905	141	218	418
Aug 1999	16,632	136	214	413
Sep 2000	24,864	0	74	256
Sep 2005	18,608	141	222	419

Note: Assumes a rate of rise of 1.35 and a rate of fall of 0.85 from the recorded baseflow either side of the event.

5. Operating Regimes

5.1 Introduction

This section presents potential 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
- identifying any constraints on water delivery, such as available airspace in irrigation channels, 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 the allocation in July, as shown in Table 11. For example, when the high reliability water share allocation in July is 100 per cent but the low reliability water share allocation is less than 20 per cent, then the suite of recommendations assigned to the dry climate year would be targeted. Allocations have been used as a surrogate for anticipated flow conditions in the Goulburn River, because the differences in within-channel flow in different climate years, previously presented in Section 4.1, are largely influenced by the use of allocations for irrigation supply. If flow conditions change rapidly, such as in a major runoff event, consideration should be given to aiming for higher volume events associated with a wetter climate year. The selection of the suite of target flows should be flexible and in response to conditions in the Goulburn River, because the flow thresholds for achieving the ecological benefits aligned with each threshold, particularly for the higher flow events, are not precisely known at the current time.

Table 11: Identifying seasonal target environmental flow recommendations.

Climate year for selecting flow recommendations	Goulburn high reliability water share allocation in July	Goulburn low reliability water share allocation in July
Extreme dry	≤70%	0%
Dry	71% - 100%	≤20%
Median	100%	21-80%
Wet	100%	>80%

Using these triggers, the frequency of extreme dry years is approximately 1.4 years in 10, dry years occur approximately 2.5 years in 10, median years occur approximately 3.6 years in 10 and wet years occur 2.5 years in 10. This data is based on modelled allocations at the start of July, but allocations from mid-July could be used if a start of July allocation is not announced.

5.3 Delivery triggers

Proposed operational triggers for delivering the suggested environmental flow proposals are presented in Table 12.

The delivery of the baseflow requirements in all years occurs continuously over the season specified in the flow recommendations, and will occur from the nominated start date. These flows are within-channel and can be delivered via releases from Lake Eildon if not already being provided (for example, to meet inter-valley transfer requirements).

The summer to autumn pulse flow of up to 6,600 ML/d has historically (since 1974) been rarely met. If this pulse flow is required as recommended in all but extreme dry years, opportunities to contribute to natural flow peaks is limited. As described in the following section on travel time, releases from Lake Eildon are likely to lag behind natural flow peaks of any runoff events from tributaries downstream of Yea. It is therefore recommended that environmental water managers liaise with the VEWH, GB CMA and G-MW to identify opportunities to deliver flows by piggybacking onto natural floods in the Acheron and Rubicon Rivers. Delivery will need to ensure that flows at Trawool do not exceed the minor flood level of 21,700 ML/d. Estimating the volumes required to meet a target of up to 6,600 ML/d downstream of Goulburn Weir will be difficult because of variability in river losses and attenuation, as well as releases and subsequent diversions at Goulburn Weir for irrigation supply and water users en route. The need for environmental water is likely to be minimised if the summer to autumn pulse can occur at a time when baseflows downstream of Goulburn Weir are higher due to inter-valley transfers for irrigation users in the Murray River. If a natural event in the upper tributaries cannot be piggybacked, environmental water managers should try to time releases with delivery of inter-valley transfers, which will depend on river operation decisions in the Murray. G-MW can provide advice on the likely timing and magnitude of inter-valley transfers in any given season.

The winter to spring bankfull event of up to 19,000 ML/d and overbank event of 25,000 to 40,000 ML/d have historically (since 1974) not been met at the required frequency. Opportunities to trigger or supplement events of this magnitude are limited by upstream flooding constraints. If a peak flow is observed on Acheron and Rubicon Rivers, water released from Lake Eildon will reach Trawool at approximately the same time as the tributary flows, contributing to the peak magnitude of the event. However, minor flooding occurs at Trawool when flows exceed 21,700 ML/d (see Table 14). It would be necessary to ensure releases from Lake Eildon did not cause or contribute to flooding of private land along this reach of the Goulburn River.

Piggybacking on events observed in tributaries downstream of Trawool would provide greater flexibility to release extra water from Lake Eildon while remaining below the Trawool minor flooding threshold. However, due to travel times along the Goulburn River, water released from Lake Eildon will not catch up to events observed on tributaries downstream of Trawool (including the Broken River).

As such, there is limited opportunity to trigger the winter to spring bankfull and overbank events. The occurrence of these events will remain reliant on natural events.

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

Climate year	Flow objective in Goulburn River (Reach 4 and 5)	Season/ timing	Average return period	Trigger for delivery
Extreme dry	310-610 ML/d baseflow	Nov-Jun	All very dry years	Maintain throughout season with releases from Lake Eildon as required.
Dry	500-830 ML/d baseflow	Nov-Jun	All dry years	Maintain throughout season with releases from Lake Eildon as required.
	6,600 ML/d for 7 days	Nov-Jun	All dry years	Liaise with G-MW to look for opportunities to deliver water from Eildon in conjunction with inter-valley transfer deliveries and/or runoff events in the Acheron and Rubicon Rivers.
	19,000 ML/d for 5 days	Jul-Oct	All dry years	Liaise with G-MW to supplement runoff events in the Acheron and Rubicon Rivers.
	25,000-40,000 ML/d for 5 days	Jul-Oct	7 years in 10	
Median	500-860 ML/d baseflow	Nov-Jun	All median years	Maintain through season.
	6,600 ML/d for 7 days	Nov-Jun	All median years	Liaise with G-MW to look for opportunities to deliver water from Eildon in conjunction with inter-valley transfer deliveries and/or runoff events in the Acheron and Rubicon Rivers.
	19,000 ML/d for 5 days	Jul-Oct	All median years	Liaise with G-MW to supplement runoff events in the Acheron and Rubicon Rivers.
	25,000–40,000 ML/d for 5 days	Jul-Oct	7 years in 10	
Wet	500-860 ML/d baseflow	Nov-Jun	All wet years	Maintain through season.
	6,600 ML/d for 7 days	Nov-Jun	All wet years	Liaise with G-MW to look for opportunities to deliver water from Eildon in conjunction with inter-valley transfer deliveries and/or runoff events in the Acheron and Rubicon Rivers.
	19,000 ML/d for 5 days	Jul-Oct	All wet years	Liaise with G-MW to supplement runoff events in the Acheron and Rubicon Rivers.
	25,000–40,000 ML/d for 5 days	Jul-Oct	7 years in 10	

The GB CMA is investigating options to use the volume stored in Goulburn Weir to release flows to coincide with natural flow peaks along the Broken River, thereby providing increasing flows in the Lower Goulburn River downstream of Shepparton. The volume released from Goulburn Weir would then require some supplementing from Lake Eildon releases. This would involve some operational adjustments, such as managing deliveries along the irrigation channels from Goulburn Weir. It may only be practically feasible during winter.

5.4 Travel time

Travel time along the Goulburn River downstream of Lake Eildon has been assessed based on recorded streamflow data and is illustrated in Figure 8. This analysis shows total travel time along the Goulburn River to be in the order of six days when upper system tributaries are not significantly influencing flow. Total travel time along the Goulburn is based on the following reach travel times:

- Lake Eildon to Trawool – one to two days.
- Trawool to Seymour – zero to one day.
- Seymour to Shepparton – one to two days.
- Shepparton to Loch Garry – one day.
- Loch Garry to McCoys Bridge – one day.

Figure 8 shows flow at Lake Eildon, Trawool and Seymour at a time when upper system tributaries (represented by the Acheron and Rubicon Rivers) are not significantly influencing flow.

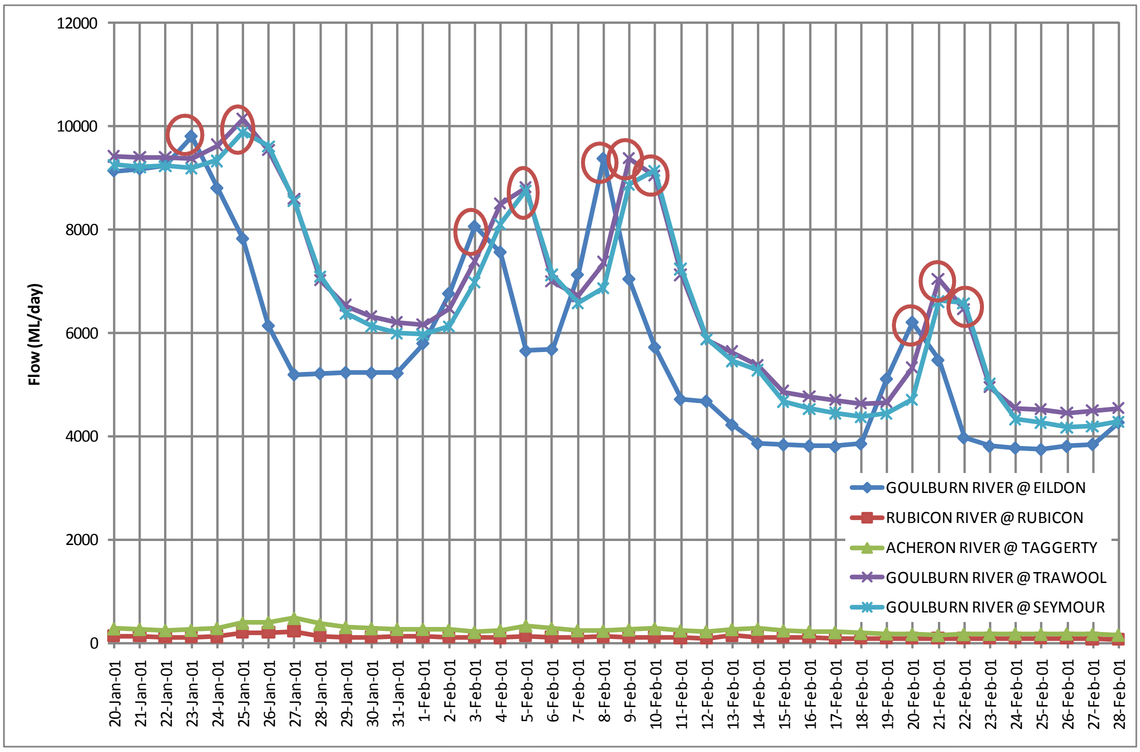

Figure 8: Goulburn River travel time: Lake Eildon to Seymour.

Figure 9 shows flow at Seymour, Shepparton, Loch Garry and McCoys Bridge at a time when the Broken River is not significantly influencing flow. This plot illustrates that travel time between Seymour and Shepparton is in the order of two days, travel time between Shepparton and Loch Garry is in the order of one day and travel time between Loch Garry and McCoys Bridge is in the order of one day.

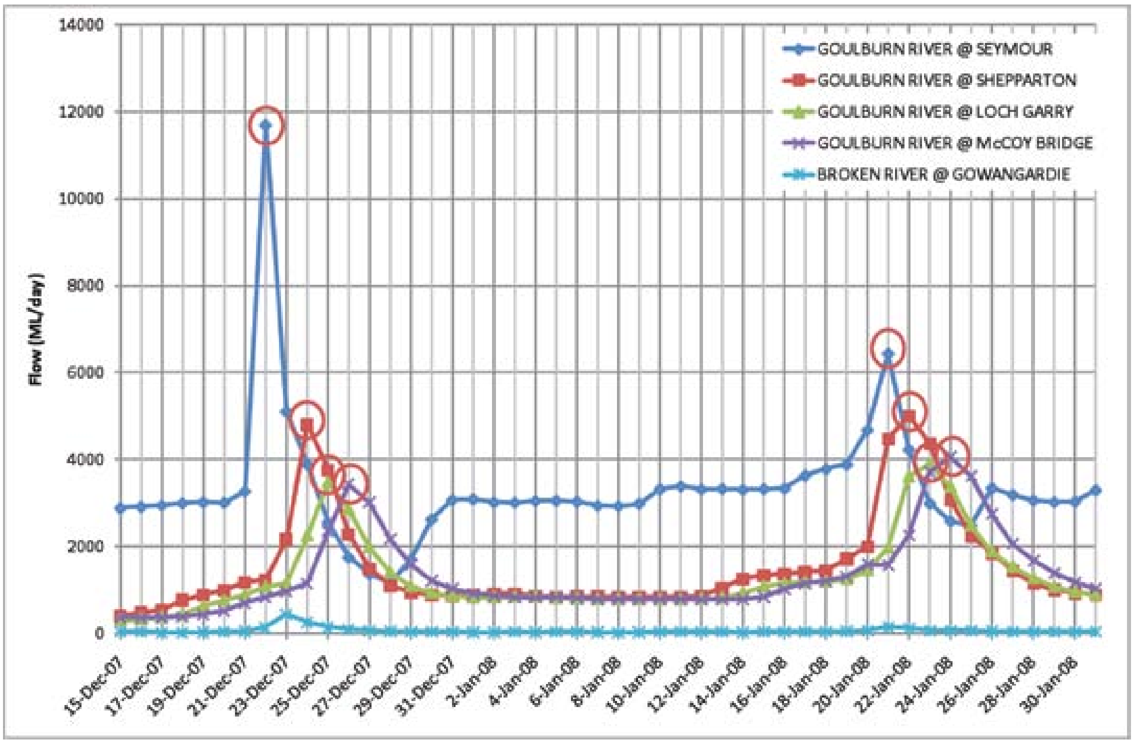

Figure 9: Goulburn River travel time: Seymour to McCoys Bridge.

Figure 10 shows flow in the upper system tributaries (Rubicon and Acheron Rivers) and at Trawool at a time when tributary inflows are driving downstream flow patterns (rather than flow at Lake Eildon). In this plot, the Rubicon and Acheron Rivers are peaking at the same time, although the Acheron River is contributing more flow. This plot shows that travel time between the peak on the outlet of the upper system tributaries and Trawool is in the order of one day. This is the same as the travel time for releases from Lake Eildon to Trawool.

This means that if a peak is observed (or predicted) on the upper system tributaries, water can be released from Lake Eildon and will reach Trawool at approximately the same time, contributing to the peak magnitude of the event.

In releasing water from Lake Eildon to supplement peak flow events from the upper system tributaries, it is important to predict total flow at Trawool (inclusive of tributary inflows and releases from Lake Eildon) to ensure releases from Lake Eildon do not cause or contribute to overbank flooding at Trawool.

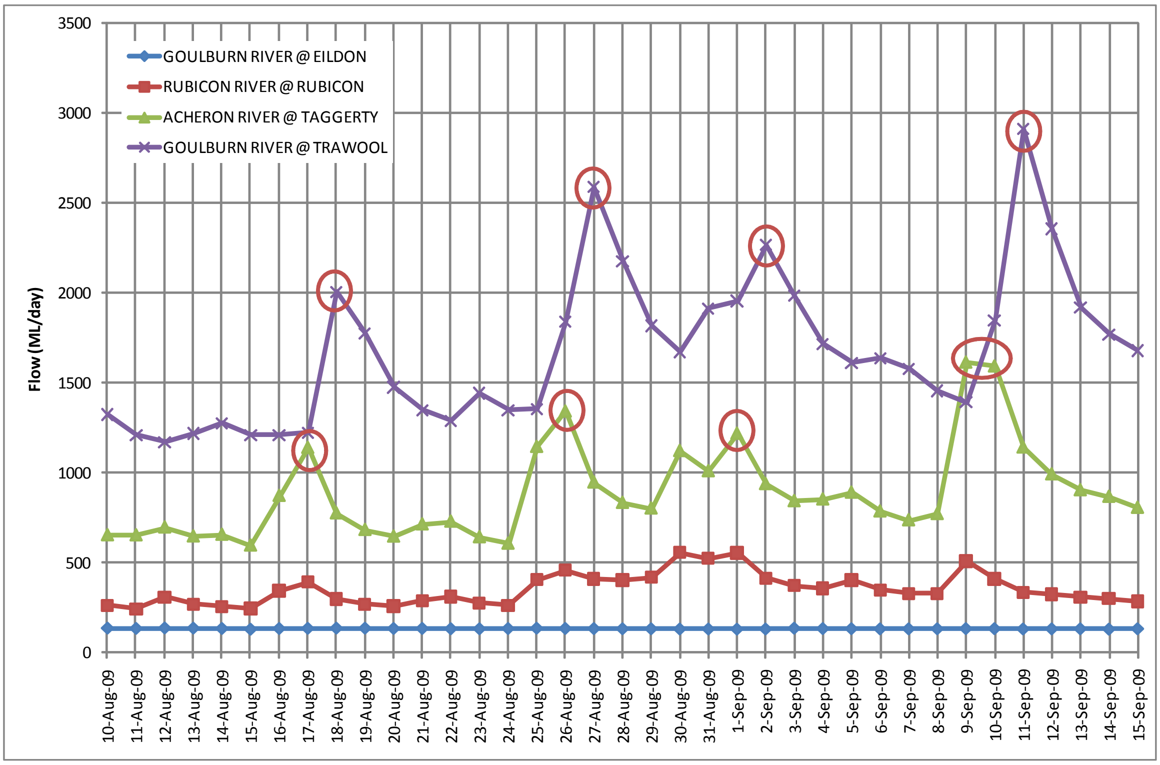

Figure 10: Goulburn River travel time: upper system tributaries.

Figure 11 shows flow on the Broken River just downstream of Lake Nillahcootie (Moorngag) and just upstream of the Goulburn River confluence (Orrvale). This plot demonstrates that travel time along the Broken River from Moorngag to Orrvale is in the order of two days. It is assumed that travel time from Orrvale to Shepparton on the Goulburn River is less than one day.

As such, peak flows observed in the upper Broken River (downstream of Nillahcootie) will reach Shepparton in approximately two days. This is less than the time taken for releases from Lake Eildon to reach Shepparton (approximately four days). Thus if a peak flow is observed in the upper Broken River, water released from Lake Eildon will not reach Shepparton in time to contribute to the event (unless the event is prolonged).

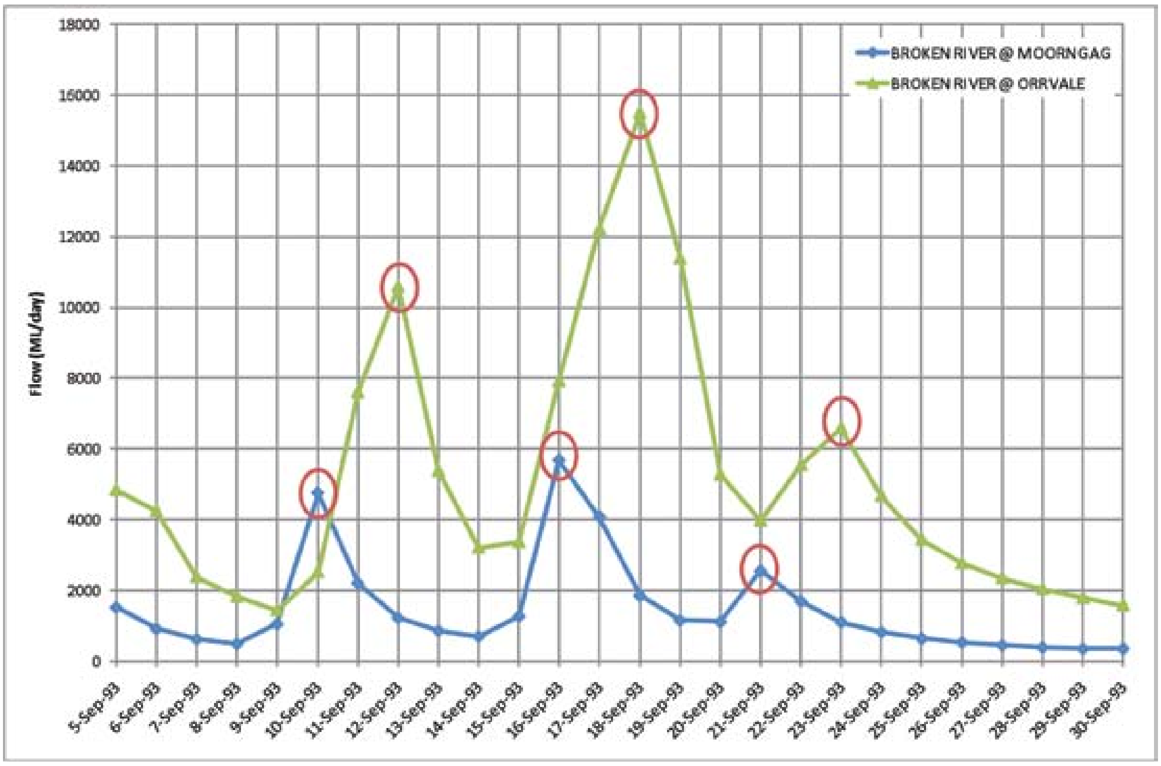

Figure 11: Goulburn River travel time: Broken River.

The volume of water required to be released from Lake Eildon to achieve a peak flow of a specific magnitude is influenced by inflows and losses along the flow path. An analysis of the correlation between flow at Shepparton and flow downstream of Goulburn Weir (Murchison) (see Figure 12) indicates that flow in the Goulburn River at Shepparton is on average approximately 38 per cent higher than flow at Murchison due to local catchment inflows downstream of Murchison (reducing the volume which must be met from releases).

The correlation between flow at different locations along the river decreases with distance upstream. This is due to the influence of system operations such as the variable nature of diversions (particularly at Goulburn Weir) and the variable nature of releases from Lake Eildon which switch on and off rapidly in response to tributary inflows and changes in demand. Further analysis of flows or extraction of modelled data is required to better understand the contribution typically made from tributaries between Lake Eildon and Goulburn Weir.

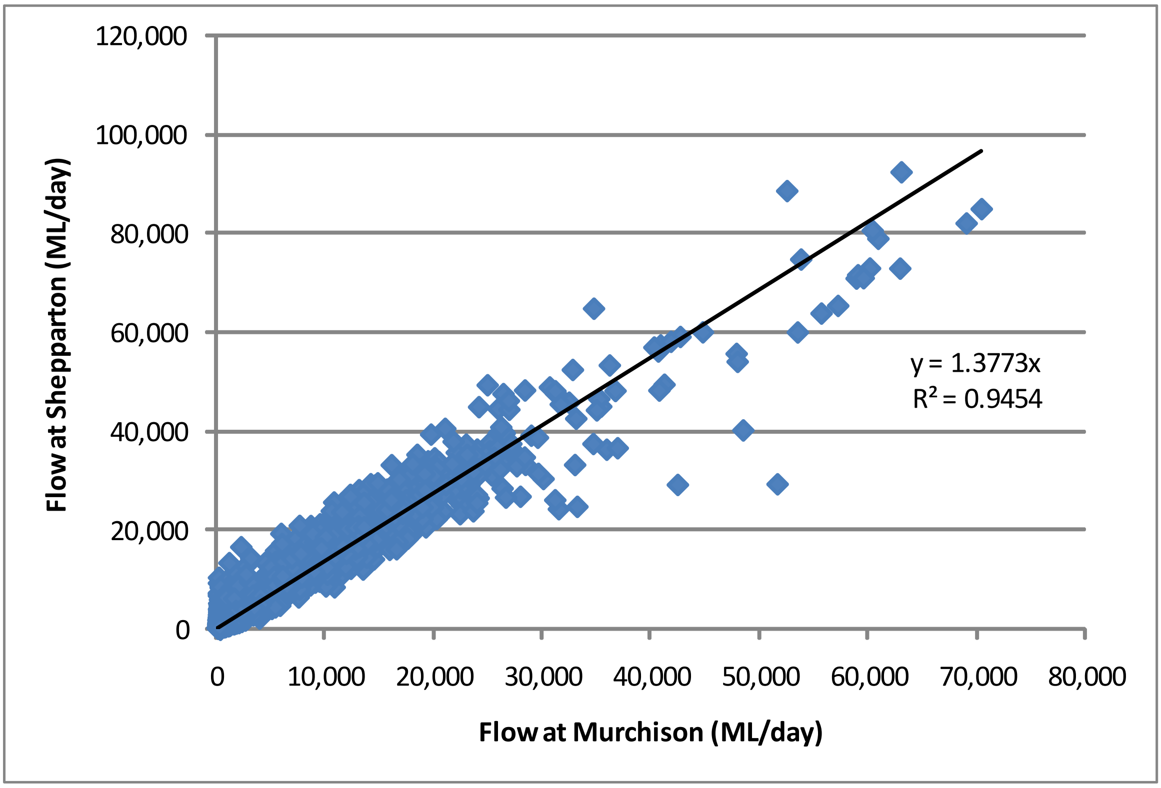

Figure 12: Correlation between flow at Shepparton and flow at Murchison.

5.5 Flooding

The Goulburn River downstream of Shepparton is confined within a levied floodway but its capacity is inadequate to convey even moderate flood events. To reduce the probability of overtopping the levees, water is allowed to pass from the floodway into Bunbartha Creek at Loch Garry, Deep Creek, Wakiti Creek, Hagens Creek and Hancocks Creek. Of these, the Loch Garry regulator has by far the highest capacity of 60,000 ML/d.

The Loch Garry regulator and levees are a part of the Loch Garry Flood Protection District. The aim of the scheme is to provide protection against frequent low level flooding. Loch Garry is a 48 bay regulator located around 16 kilometres downstream of Shepparton. Prior to the construction of the levees, floodwater would have regularly broken out of the Goulburn River at Loch Garry and flowed into Bunbartha Creek. Operation of Loch Garry is based on Shepparton river heights. Removal of bars commences 24 hours after the Shepparton gauge level has exceeded 10.36 metres (110.487 mAHD) with all bars being removed 24 hours after the river level at Shepparton has exceeded 10.96 metres. The capacity of the levied river floodway downstream of Shepparton is shown in Table 13.

Table 13: Capacity of the levied river floodway downstream of Shepparton (Water Technology 2005).

River Reach	Capacity (ML/d)	
Upstream of Loch Garry (Medland Rd)	185,000 ML/d	(40 year ARI)
Loch Garry to Deep Creek Outlet	85,000 ML/d	(7 year ARI)
Deep Creek Outlet u/s McCoys Bridge	75,000 ML/d	(5 year ARI)
McCoys Bridge	65,000 ML/d	(4 year ARI)
Downstream of McCoys Bridge to Yambuna Forest	60,000 ML/d	(3 year ARI)
Yambuna Choke	37,000 ML/d	(2 year ARI)

Flows corresponding to minor flood, moderate flood and major flood levels are shown in Table 14. Minor flooding results in inconvenience, with low lying areas next to watercourses inundated, requiring the removal of stock and equipment and the closure of minor roads. For moderate flooding, some houses may require evacuation. Under major flooding, properties and towns are likely to be isolated and major traffic routes closed, with numerous evacuations required (SKM 2006).

It should be noted that the recommended overbank (25,000 to 40,000 ML/d at Shepparton) flood event in the Lower Goulburn River is above the minor flood threshold at Shepparton, Trawool and Seymour. As such, further consultation is required with G-MW, DSE and the VEWH before environmental water could be used to contribute to these peak flow events.

Table 14: Goulburn River flood flows (SKM 2006).

Station	Name	Minor Flood (ML/d)	Moderate Flood (ML/d)	Major Flood (ML/d)
405203	Goulburn River at Lake Eildon	14,500	26,000	40,000
405201	Goulburn River at Trawool	21,700	41,500	83,000
405202	Goulburn River at Seymour	22,800	38,900	80,900
405200	Goulburn River at Murchison	29,200	58,800	79,670
405204	Goulburn River at Shepparton	22,500	67,780	87,000
405232	Goulburn River at McCoys Bridge	29,200	50,000	62,600

Flows from the Goulburn River can only pass through three gaps in the Bama Sandhills:

- at the Yambuna Choke
- through a flood course associated with Madowla Lagoon
- at high river stage, along Yambuna Creek to Warrigal Lagoon and Kanyapella Basin.

The last two of these three gaps are now blocked by levees. Flood flows also find their way through a fourth gap in the sandhills via overflows to Deep Creek and the Murray River.

The maximum capacities of each of the outlet structures along the Lower Goulburn are given in Table 15. Note that these figures are estimates of the maximum capacities during major floods, when the outlets are surcharged. Flows through Loch Garry, for example, would be significantly reduced for small to medium sized floods (Water Technology 2005).

Table 15: Lower Goulburn outlet structure capacities (Water Technology 2005).

Outlet	Capacity (ML/d)
Loch Garry regulator	60,000
Deep Creek outlet	3,000
Wakiti Creek outlet	3,100
Hagens Creek outlet	100
Hancocks Creek outlet	3,700

5.6 Storage releases

The minimum flow immediately downstream of the Lake Eildon Pondage is established by Clause 11 of the Goulburn Bulk Entitlement Conversion Order 1995. The general minimum flow requirement is 120 ML/d, however if 24 month inflows exceed trigger levels, additional passing flows described in Clause 6 of the Bulk Entitlement become available. Under these provisions, minimum flows increase to 250 ML/d, and an additional 80,000 ML can be passed downstream during November, to provide water to effluent lagoons for one day up to a maximum release of 16,000 ML/d.

During the irrigation season, releases to satisfy downstream requirements generally exceed the minimum flow requirements. G-MW bases its requirements for Lake Eildon releases on:

- Daily assessment of release requirements:
  - For supply of bulk water orders for irrigation areas, diversion customers or other authorities, including inter-valley transfers.
  - To minimise unregulated releases at Goulburn Weir by taking into account irrigation demand, natural catchment inflow below Lake Eildon and weather conditions.
  - To supply transmission losses.
  - For release requirements downstream of Goulburn Weir.
- Target operating levels at Waranga Basin, to avoid long periods of high release from Lake Eildon.
- Maximum regulated release from Lake Eildon, which is 10,000 ML/d.

Inter-valley transfers have resulted from net trade from the Goulburn to the Murray River systems. Water may be called out from Lake Eildon at different times of the year to assist in meeting Murray River requirements. The transfer of water from Lake Eildon to the Murray River can be achieved through the following river systems:

- Goulburn River, utilising the reach downstream of Goulburn Weir.
- Broken Creek, utilising the East Goulburn Main Channel to outfall water to Broken Creek and then through to Rice's Weir.
- Campaspe River, utilising the Waranga Western Channel to outfall water to the Campaspe downstream of Campaspe Siphon.

Additional water loss is estimated and applied when using the Broken Creek and Campaspe River bypass routes.

When Lake Eildon is being operated to meet a downstream release requirement, G-MW places an order for the flow required downstream of the regulating pondage with AGL Hydro. AGL Hydro then operates the power station and regulates the pondage to best meet requirements (within agreed pondage operating limits), whilst passing the ordered flow downstream. This includes communicating what flows can be passed through the pondage hydro station with the power station operator. If the Lake Eildon power station is unavailable, then G-MW regulates water using the low level outlet, spillway valves or spillway gates, into the pondage. AGL Hydro continues to manage releases from the pondage to meet downstream flows.

The pondage provides AGL Hydro with some flexibility to make higher releases during periods of higher electricity demand without additional water being released downstream of the pondage. However, there are times when releases for electricity generation will exceed the pondage's ability to regulate the water. AGL Hydro has up to 80,000 ML a year that it can pass downstream of the pondage in addition to G-MW's downstream requirements. The pattern of releases is unknown, but is likely to be affected by electricity pool prices, the volume of irrigation releases already generating electricity, and the ability of AGL Hydro to generate power from its portfolio of electricity supply sources. Releases must comply with the conditions of the bulk entitlement as follows:

- Maximum rate of rise is 150 mm/h with a maximum flow increase of 3,500 ML/d.
- Maximum rate of fall is an instantaneous fall of 150 mm and then 30 mm/h to a maximum of 450 mm/d for the first day, with 30 mm/h and 300 mm/d thereafter.

The two target curves in Schedule 5 of the G-MW Goulburn Bulk Entitlement 1995 form the basis of the flood operating procedures for Lake Eildon (Figure 13). The two curves represent the target filling for normal and wet years, with the wet year curve used where G-MW considers that wet conditions will continue, and the risk of Lake Eildon not filling is low.

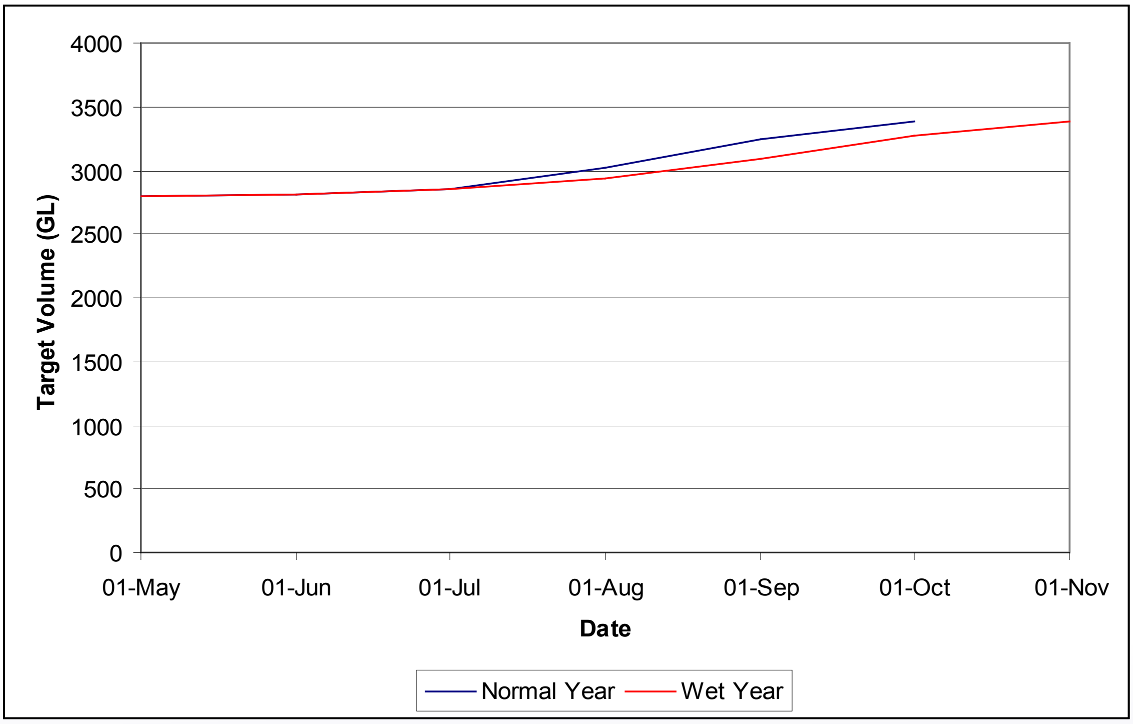

Figure 13: Lake Eildon filling targets – Schedule 5 of the G-MW Bulk Entitlement (SKM 2006).

Operations will initially allow Lake Eildon to fill to the selected target curve. Once the target curve has been reached, releases are made to keep to the target curve. During periods of high inflows, the storage may be allowed to exceed the target curve to provide some flood mitigation. Releases are then made to return the storage to the target storage level. The magnitude and timing of releases is based on the rate of inflow to the storage, any ability to surcharge the storage, downstream inflows and flooding, and the potential for further significant inflows. The release capacity from Lake Eildon is shown in Table 16.

Table 16: Lake Eildon discharge capacity (SKM 2006).

Storage Volume (% of capacity)	Storage Volume (ML)	Storage Level (m)	Discharge Capacity (ML/d)
10.0	338,790	248.9	20,500
16.6	562,391	255.3	20,300
20.0	677,580	257.8	23,600
30.0	1,016,370	264.2	24,500
40.0	1,355,160	269.2	23,400
50.0	1,693,950	273.5	25,000
60.0	2,032,740	277.2	26,300
70.0	2,371,530	280.5	27,450
77.4	2,622,235	282.8	28,200
80.0	2,710,320	283.6	34,330
90.0	3,049,110	286.3	92,835
100.0	3,387,900	288.9	183,930

Goulburn Weir, which forms Lake Nagambie, is a concrete and masonry structure that provides a sufficient water level to allow diversions to the Stuart-Murray Canal, Cattanach Canal and the East Goulburn Main Channel. At its full supply level of 124.24 mAHD its capacity is 25,000 ML, and it has a surface area of 1,130 hectares. Lake Nagambie is used extensively for recreation.

The offtake to the Stuart-Murray Canal is located immediately west of the weir structure, while offtakes to the East-Goulburn Main Channel (east side of the weir) and Cattanach Canal (west side of the weir) are located further upstream of the weir.

The Goulburn Bulk Entitlement sets minimum flow criteria at two points downstream of Goulburn Weir. The first immediately downstream of Goulburn Weir requires a weekly average of 250 ML/d, and a minimum daily rate of 200 ML/d. The second passing flow requirement occurs at McCoys Bridge and varies over the year. Requirements are:

- For November to June inclusive a minimum average monthly flow of 350 ML/d and a daily requirement of no less than 300 ML/d.
- For July to October inclusive a minimum average monthly flow of 400 ML/d with a daily requirement of not less than 350 ML/d.

Other demands downstream of Goulburn Weir include in-valley consumptive demand from rural and urban customers, and any inter-valley transfer volumes to be passed to the Murray River.

Demands downstream of Goulburn Weir and minimum passing flows at McCoys Bridge can be met fully or in part by unregulated tributary inflows, including inflows from the Broken River.

Goulburn Weir operations need to consider meeting downstream requirements, maintaining discharge capacities from the weir and maximising the volume of unregulated inflows that can be harvested to Waranga Basin. During the June to September period, with no or low demand requirements, the operating level of Goulburn Weir is generally varied within 300 mm below full supply level (FSL) to increase harvesting capacity. Up to 7,000 ML/d can be harvested into the Waranga Basin. However as irrigation demand and the need to allow the offtakes to operate at or near capacity increases, the ability to vary the level at Goulburn Weir diminishes. In addition, the community around Lake Nagambie generally prefers the pool level to remain near FSL for public amenity reasons.

Inflows exceeding the diversion capacity to Goulburn Weir can be harvested up to FSL, however once the storage reaches FSL all additional inflows above diversion capacity are passed downstream.

5.7 Interactions with other assets

The Goulburn system, which supplies the Lower Goulburn River, is also a source of supply for:

- baseflows in Broken Creek (via the East Goulburn Main Channel)
- deliveries along the Waranga Western Channel to the Campaspe and Loddon Rivers and the Boort wetlands
- deliveries to the Murray River sites, of which Koondrook-Perricoota Forest is the closest to the outlet of the Goulburn River.

Co-ordination of flow events with watering of Barmah-Millewa Forest is likely to provide benefits for the Murray River sites being watered downstream of the Goulburn River. Travel time along the Murray River from Hume Dam is longer than the travel time along the Goulburn River from Lake Eildon, so environmental water managers are able to order deliveries to match outflows from the Barmah-Millewa Forest. However, high or flood flows from the Goulburn River can cause Murray River flows to bank up (back water impacts), forcing more Murray River water north through the Edward-Wakool system and reducing flow rates through the Barmah-Millewa Forest. It is not clear at what magnitude back-water impacts commence and this is an area requiring further investigation.

It is also noted that flooding of the Goulburn River into Koondrook-Perricoota Forest via the Murray River can create water quality problems in the Wakool River, such as blackwater events, which occur when organic matter from the floodplain (or upper banks) becomes entrained in the water column, particularly during warm conditions.

5.8 Water delivery costs

5.8.1 Delivery costs

Environmental water holdings in the Goulburn system incur an annual service point fee of $200. However, there is no delivery cost for environmental water delivered from Lake Eildon to the Goulburn River.

Storage costs for 2011-12 for the Goulburn system are $3.54 per ML held in the spillable water account, $6.98 per ML of high reliability water share and $3.54 per ML of low reliability water share. Storage charges are also applicable to water shares held in other systems, from which water may be traded to the Goulburn system (e.g. the Murray River).

Note that delivery charges are subject to review on an annual basis. Refer to http://www.g-mwater.com.au/customer-services/feesandcharges for more information.

5.8.2 Carryover costs

Carryover is unlimited in the Goulburn system. Any allocation and carryover greater than 100 per cent of the total entitlement is quarantined in the spillable water account. This water becomes available to trade or use once Goulburn Murray Water makes a declaration that there is a low risk (less than 10 per cent probability) of the storage spilling later in the season. After the declaration is made, any water that has not spilled is transferred out of the spillable water account back into the available balance of the allocation bank account, and a volumetric charge is applied (G-MW 2011).

6. Governance

6.1 Water planning responsibilities

The Northern Region Sustainable Water Strategy (NRSWS) provides the strategic direction for water management across northern Victoria (DSE 2009). The NRSWS also presents the community an agreed level of health target for the Goulburn River system. The Victorian Government has agreed to try and meet the health target through various mechanisms, including the use of environmental water. G-MW has responsibility for the planning and delivery of water to the Lower Goulburn River. In doing so, G-MW collaborates with:

- The GB CMA to deliver environmental water, including the Goulburn system water quality reserve, and inter-valley transfers to the Murray River. Note that while G-MW can make recommendations regarding the delivery of inter-valley transfers to support GB CMA objectives, the actual delivery of inter-valley transfers is governed by the MDBA who are working towards the management of the larger Murray-Darling Basin and are not compelled to follow G-MW's recommendations.
- The VEWH, responsible for managing Victorian environmental water holdings.

Water shares in the Goulburn system can be used to deliver water from the headworks storage in Lake Eildon, Goulburn Weir, Waranga Basin and Greens Lake.

6.2 Delivery partners, roles and responsibilities

The major strategic partners in delivering water to the Lower Goulburn River include:

- The VEWH as the manager of Victorian environmental water holdings.
- GB CMA as the environmental water manager for the Goulburn system.
- G-MW as the BE holder, manager of the major reservoirs and irrigation areas in the catchment, and also the licensing authority responsible for groundwater and surface water licensed diversions.
- Goulburn Valley Water is responsible for urban water supply in the catchment.

Both the GB CMA and G-MW cooperate with the VEWH in the delivery of environmental water, as well as with the MDBA in relation to water transfers (inter-valley transfers) from the Murray system.

6.3 Approvals, licences, legal and administrative issues

6.3.1 Water shepherding and return flows

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 losses (if any) are taken into account
- the return flows can be delivered in line with the timing requirements of the downstream user, purchaser or environmental site
- the system operator can re-regulate the return flows downstream, with a known and immaterial spill risk, if the entitlement holder is requesting credits on a regulated system.

The Australian Government does not currently have the ability to deliver water from its water shares for the Goulburn system, so it must transfer its allocations to the VEWH for water to be used. If environmental water allocations are transferred to the VEWH then the ability to reuse those flows in the Murray River depends on the conditions of the individual entitlements.

If the point of delivery for environmental water is specified as at McCoys Bridge, which is near the confluence of the Goulburn River and Murray River, then this will ensure that all reaches of the Goulburn River receive the benefit of environmental water released from Lake Eildon.

If in the future environmental water is delivered directly to the Lower Goulburn River, then credits for return flows to the Murray River can be granted under G-MW's bulk entitlements for the Victorian Murray and Goulburn systems. The application for the credits would be submitted by G-MW and the credits would be granted to G-MW. Environmental water managers would then need an agreement with G-MW and MDBA Murray River Operations to have these return flows credited to their allocation bank account for the Murray River downstream of Barmah Choke.

6.4 Trading rules and system accounting

6.4.1 Water trading

The Goulburn River from Lake Eildon to Goulburn Weir is located in Trading Zone 1A, while the Goulburn River from Goulburn Weir to the Murray river is located in Trading Zone 3. A map showing the Victorian and southern NSW water trading zones is shown inFigure 14. Table 17 provides an overview of trading capability between zones.

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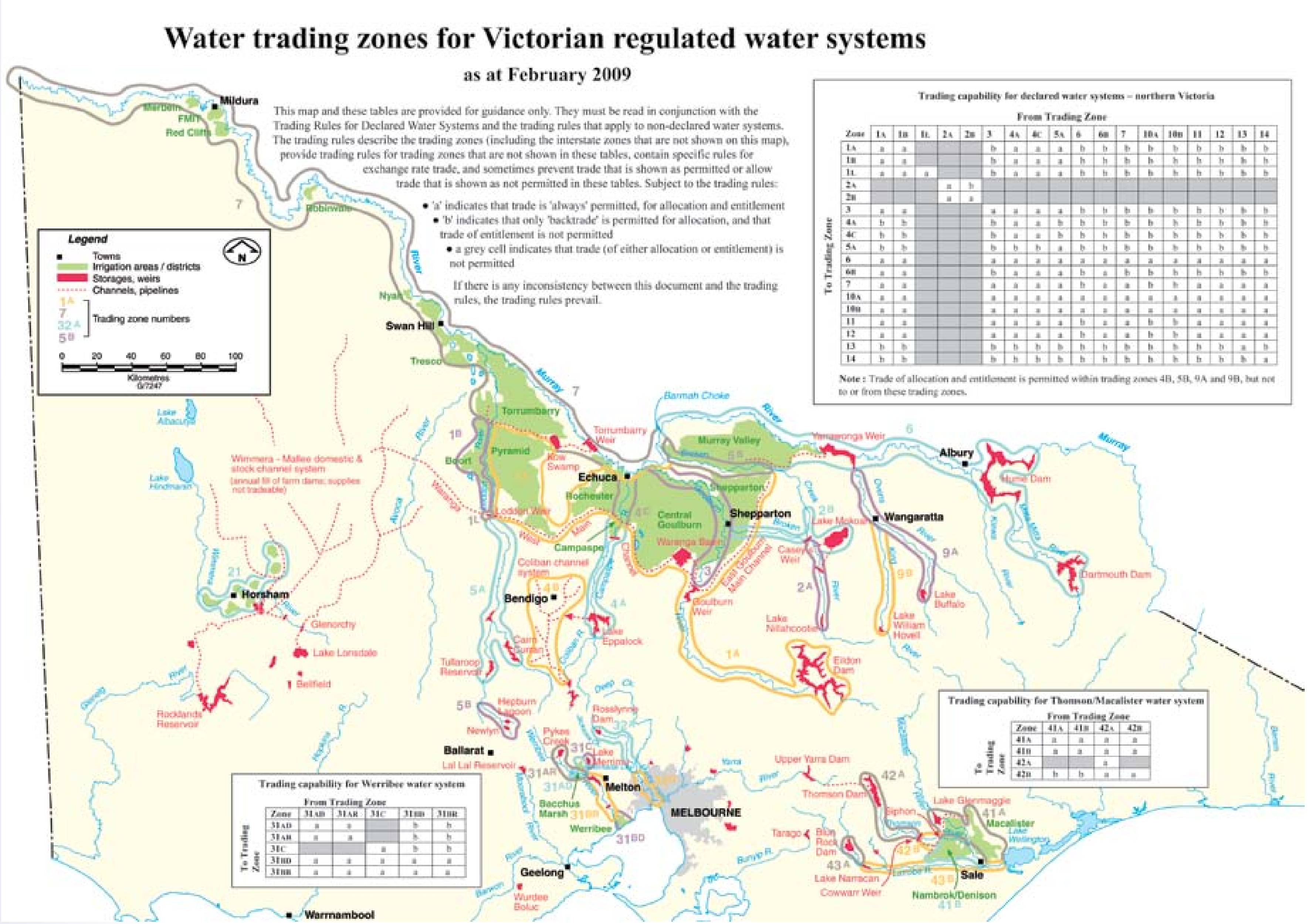

Figure 14: Trading zone boundaries (Victorian Water Register 2011).

Table 17: Summary of trading rules.

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

Additional Trading Rules

All trade except to unregulated tributaries is with an exchange rate of 1.00. Trade into the unregulated river zones of the Goulburn (zones 110, 111, 112 and 130) can only be transferred as a winterfill licence, which becomes available in the following year. The water share volume is increased by 19 per cent when transferred to a winterfill licence, and decreased by 19 per cent when bought from a winterfill licence. Trade (of allocation or entitlement) into Murray Irrigation Limited areas (zone 10B) attracts a 10 per cent loss of share volume.

Permanent trade is currently limited to 4 per cent per year from irrigation districts in Victoria. G-MW 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. For more information on water trading rules, see the Victorian Water Register (http://waterregister.vic.gov.au/).

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

- Interstate – 90 per cent of allocation trades between NSW/Victoria processed within 10 business days.
- Interstate – 90 per cent of allocation trades to/from South Australia processed within 20 business days.
- Intrastate – 90 per cent of allocation trades processed within 5 business days.

This means that the 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 occurs without the use of a broker, the fees are currently less than $80 for Victoria within state trade. See the Victorian Water Register for Victorian fee schedules at http://www.waterregister.vic.gov.au/Public/ApplicationFees.aspx.

6.4.2 Water storage accounting

Unlimited storage carryover is allowed in the Goulburn system, but water above 100 per cent of the water share volume can be quarantined in a spillable water account when there is risk of Lake Eildon spilling. Any water in the spillable water account cannot be accessed until the risk of spilling has passed (assessed by the G-MW Water Resources Manager based on storage levels and likely inflows). If a spill occurs, prior to a declaration being made by G-MW, then the balance held in the spillable water account will be reduced in proportion to the volume to spill (G-MW 2011). The annual deduction for evaporation is 5 per cent of carried over volume. The fee for transferring water from the spillable water account back to the allocation bank account is $3.52 per ML for the Goulburn system. See http://www.g-mwater.com.au/customer-services/carryover#1 for more information.

6.4.3 Water delivery accounting

G-MW has an allowance for conveyance losses within its bulk entitlement for the Goulburn system. If conveyance losses increase because water is being delivered to environmental assets, then these additional losses would be negotiated between G-MW and environmental water holders.

7. Risk assessment and mitigation

The risk assessment outlined in Table 18 provides an indication of the risks associated with the delivery of environmental water in the Lower Goulburn 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. A framework for assessing risks has been developed by SEWPaC and is included at Appendix 6.

Table 18: Risk associated with water delivery in the Lower Goulburn River.

Risk type	Description	Likelihood	Consequence	Risk level With control in place	Controls
Acid sulfate soils	There is no evidence of acid sulfate soil issues along the Goulburn River.	Unlikely	Moderate	Low	Maintenance of continuous flows should minimise this risk.
Salinity	Releases from Lake Eildon and Goulburn Weir to the Lower Goulburn River are of good quality and do not pose salinity risks at the volumes proposed.	Unlikely	Minor	Low	Salinity is monitored and the Goulburn water quality reserve could be called upon to reduce (dilute) saline water, if this was necessary (unlikely).
Invasive species	Carp breeding can occur, along with that of native fish. Invasive aquatic macrophytes (e.g. *Sagittaria*) occur across the region.	Likely	Moderate	Medium	Carp - none practicable. Invasive aquatic macrophytes – continued surveillance and eradication or control.
Low DO (e.g. from blackwater events)	Fish kills have occurred in the Goulburn River, with low DO being implicated although the exact cause of these deaths was difficult to determine (e.g. Koehn 2004, Sinclair 2004). Recent low DO events have been attributed to catchment runoff from bushfire-affected tributaries. A blackwater event and fish kill has recently (December 2010) occurred with the second of two floods experienced along the river this winter/spring.	Possible, depending on antecedent conditions.	Major	High	Continue the GB CMA monitoring of DO to assess recovery in DO expected as flow is dominated from Lake Eildon releases, rather than inflows from tributary catchments (including bushfire affected catchments). Most flows proposed will not leave the river channel, reducing the risk of low DO and blackwater that might occur with flooding. The risk of low DO with flooding could also be reduced by limiting controlled overbank flows to winter-spring.
Water loss	There is high uncertainty regarding magnitude of losses downstream of Lake Eildon, particularly at high flow rates. Modelling suggests that in the order of 100 GL can be retained on the floodplain in overbank events (G. Earl, GB CMA, pers. comm. 2011).	Likely	Minor	Medium	Review losses along Goulburn River. Allow for losses, if necessary, when estimating allocations.
Estimation of water availability and volumes required	Volumes associated with water delivery options depend on modelling. Modelling accuracy may result in underestimation of the volumes actually required. This increases the likelihood of shortfalls in actual volumes of water required to achieve objectives.	Possible	Moderate	Medium	Confirmation that volume(s) released achieve the desired hydrological and ecosystem outcomes and adjustment of volumes as required (within flow constraints – see flooding risks below).
Cold water releases from Lake Eildon.	The release of colder bottom waters from Lake Eildon mainly affects water temperature between Lake Eildon and Seymour. It is not expected to affect water temperature below Goulburn Weir.	Unlikely	Minor	Low	

Risk type	Description	Likelihood	Consequence	Risk level With control in place	Controls
Flooding	Risk of flooding sites along the river, commencing at 14,500 ML/d downstream of Lake Eildon.	Unlikely	Moderate	Low	Flows resulting from environmental water releases will be actively managed by river operators to remain below minor flood levels (14,500 ML/d immediately downstream of Lake Eildon).
	Excessive erosion and bank instability	Unlikely	Moderate	Low	Appropriate rates of rise and fall at Lake Eildon avoid excessive bank erosion.
	Loss of public amenity and risk to recreational users of the river.	Possible	Minor	Low	Notification of potential loss of public amenity and potential hazards with delivery of flow events.
	Inability to achieve environmental objectives for overbank events due to flow constraints.	Likely	Moderate	Medium	Overbank flow objectives are not currently feasible due to delivery constraints.

8. Environmental Water Reserves

8.1 Environmental water provisions

G-MW's bulk entitlement (Eildon-Goulburn Weir) specifies a number of environmental water provisions. Minimum passing flows under the entitlement are:

- A minimum flow of 120 ML/d from the Eildon Pondage Weir. This is increased to 250 ML/d when 24-month Lake Eildon inflows are high. Threshold 24-month inflows are listed in Clause 6 of the entitlement.
- A minimum average weekly flow of 250 ML/d from Goulburn Weir over any seven day period, at a daily rate of no less than 200 ML/d.
- Any additional flow necessary to maintain a minimum average monthly flow at the McCoys Bridge gauging station of 350 ML/d for the months of November to June inclusive (at a daily rate of no less than 300 ML/d) and 400 ML/d for the months of July to October inclusive (at a daily rate of no less than 350 ML/d).

Other environmental water specified under the entitlement includes:

- 80,000 ML for flood release. This water is available to be released below Eildon Pondage Weir in November under very specific circumstances relating to 24 and 12 month inflows and maximum release constraints.
- 30,000 ML for water quality. This water is available only as required to maintain water quality in the waterway.

8.2 Current water holdings

Commonwealth environmental water holdings (as at October 2010) in the Goulburn system are summarised in Table 19. These include 65,000 ML of high reliability water share and 10,000 ML of low reliability water share in the Goulburn system. The volume of Commonwealth environmental water available for use in the Goulburn system can be increased at any time by selling allocations tagged as sourced from elsewhere in the southern connected Murray-Darling Basin and purchasing an equivalent volume in the Goulburn system, subject to the trading rules described in Section 6.4 and the availability of water for purchase in the Goulburn system. The volume of Commonwealth environmental water elsewhere in the southern Murray-Darling Basin (as at October 2010) includes up to approximately 194,000 ML upstream of the Barmah Choke and 308,000 ML downstream of the Barmah Choke. These volumes continue to change as the Australian Government continues its purchasing of water entitlements – the most up to date figures can be found at www.environment.gov.au/ewater.

Environmental water currently held under Bulk Entitlements by the VEWH in the Goulburn system are summarised in Table 20.

.

Table 19: 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*	70.0	
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
	20,820.0	Supplementary
Goulburn	64,919.6	High reliability water share
	10,480.0	Low reliability water share
Broken**	20.0	High reliability water share
	4.2	Low reliability water share
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 (excluding Ovens, Broken and Murrumbidgee licences)	**193,628.0**	**High security/reliability**
	114,371.0	**Low security/reliability**

Notes:

* 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 20.0 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.

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

Table 20: Environmental water held by the VEWH in the Goulburn system.

Water holding	Volume	Comments
Environmental Entitlement (Goulburn System – The Living Murray) Further Amending Order 2009	141,046 ML of low reliability water shares (sales package). 19,164 ML of high reliability water shares (G-MW recovery package). 20,461 ML of high reliability water shares (Shepparton irrigation area modernisation project). 15,780 ML of low reliability water shares (Shepparton irrigation area modernisation project).	Committed to meet Living Murray objectives, but may be useful in the Lower Goulburn in transit.
Bulk Entitlement (Goulburn System – Snowy Environmental Reserve) Amendment Order 2009	3,900 ML of high reliability water share (pipelining of Normanville waterworks district). 14,812 ML of high reliability water share (Goulburn system improved measurement of small volume supplies to irrigation districts program). 2,000 ML of high reliability water share (Goulburn strategic measurement project).	Generally released in summer to supply Murray irrigation demands.
Goulburn River Environmental Entitlement 2010	1,432 ML of high reliability water share (Wimmera-Mallee Pipeline Savings)	Trading zone 1B
Environmental Entitlement (Goulburn System – Environmental Water Reserve) 2010	Prior to the completion of Stage 1 of the Northern Victoria Irrigation Renewal Project (NVIRP): The volume of water that has been allocated to the environment from the modernisation savings account. After the completion of Stage 1: The volume equivalent to one-third of the total volume saved in the Goulburn component of the Goulburn Murray Irrigation District, with the characteristics of high reliability and low reliability water shares.	Exact volumes to be confirmed after completion of NVIRP works. This entitlement was gazetted but was disallowed in the Victorian Parliament in June 2010.

8.3 Seasonal allocations

Victorian allocations are announced by G-MW twice monthly and are published at http://www.g-mwater.com.au/news/allocation-announcements/current.asp. Long-term seasonal allocations for the Goulburn system and Murray River are shown for October and April as indicative of spring and autumn in Figure 15 and Figure 16. This information is sourced from the MSM-Bigmod post-TLM run (#22061).

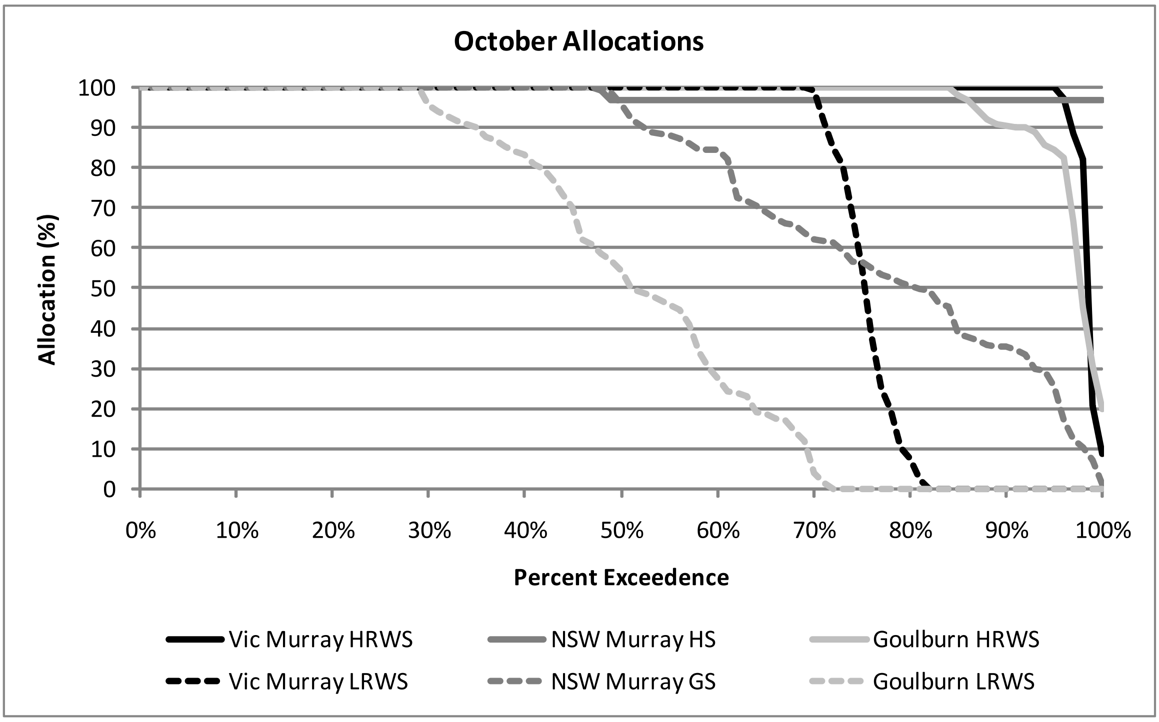

Figure 15: October seasonal allocations for the Goulburn and Murray River systems.

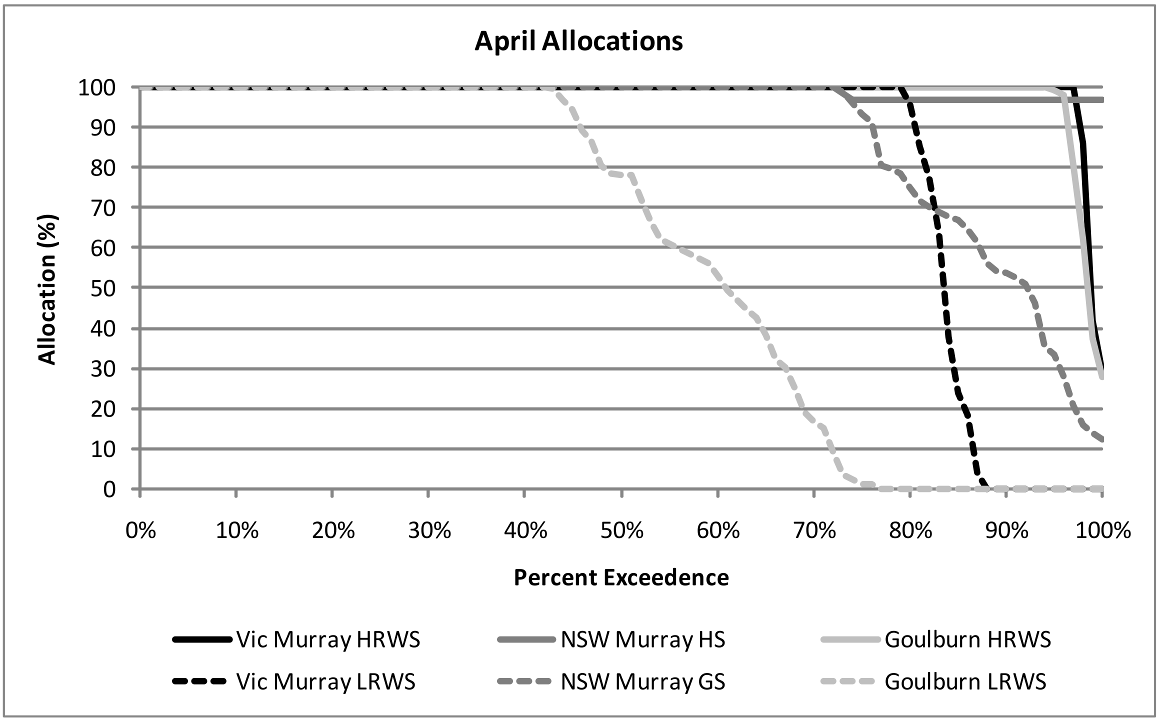

Figure 16: April seasonal allocations for the Goulburn and Murray River systems.

The allocation expected to be available (in terms of announced allocation) to the environment under different climate conditions is summarised in Table 21. The volume of water expected to be available to the environment under different climate conditions is summarised in Table 22. 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 that around 20 per cent of high reliability water shares (13,000 ML based on October 2010 holdings) would be expected to be available in the Goulburn system in spring of a very dry year and around 100 per cent of high reliability water shares and 95 per cent of low reliability water shares (75,000 ML based on October 2010 holdings) would be expected in a wet year. Note that the models used to derive these allocations can over-estimate allocation in very dry years.

Tables 21 and 22 were provided by SKM and based on allocation information from the MSM-Bigmod model of the Murray River system with The Living Murray deliveries in place (run #22061).

Table 21: 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	100
Broken	High reliability water share	20.0	1	96	97	98	1	100	100	100
	Low reliability water share	4.2	0	0	0	0	0	100	100	100
Campaspe	High reliability water share	5,124.1	33	100	100	100	43	100	100	100
	Low reliability water share	395.4	0	100	100	100	0	100	100	100
Loddon	High reliability water share	1,179.0	0	100	100	100	0	100	100	100
	Low reliability water share	527.3	0	2	54	96	0	16	78	100
South Australia	High reliability	43,297.4	44	100	100	155	62	100	100	102

Table 22: Likely volume available to the environment from 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
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.

8.4 Water availability forecasts

A description of likely water availability for the Victorian Murray and Goulburn systems is provided by G-MW when allocation announcements are made. Allocation announcements are generally made on the 15th of each month (or the next business day). However, when allocations to high reliability water shares are less than 100 per cent, 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, G-MW publishes a seasonal allocation outlook prior to the start of each irrigation season providing a forecast for opening October and February allocations for the following season. The seasonal allocation outlooks are published on G-MW's website (see Media Releases). 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

Assessing ecosystem response to specific environmental flow releases as a form of intervention analysis is a challenging exercise (Chee et al. 2006). Being able to apply traditional study designs is often problematic, as control sites (similar features to the test site, but without the intervention) are usually lacking (i.e. there is not another Goulburn River). Similarly, establishing 'before' conditions is difficult given the nature of river regulations and flows delivered from natural rainfall-runoff events.

The Victorian Environmental Flows Monitoring and Assessment Program (VEFMAP) was established specifically to assess ecosystem response to new environmental flow regimes. VEFMAP is being implemented across northern Victorian rivers, including the Goulburn, Campaspe and Loddon Rivers (Chee et al. 2006, SKM 2007). Water quality and quantity is monitored as part of the Victorian Water Quality Monitoring Network and the North East Regional Water Monitoring Partnership (NERWMP). The following section provides a guide to the parameters that could be considered for future monitoring of environmental water releases. They do not provide guidance on aspects of study design, site selection and sampling frequency.

There are numerous long-term flow gauges along the Goulburn River. Key streamflow gauges are listed in Table 23. A full list of available streamflow gauges can be found on the Victorian Water Resources Data Warehouse (DSE 2010). G-MW collects operational data for headwork storages and irrigation distribution channel systems.

Table 23: Flow monitoring along the Goulburn River.

Reach Number	Reach Description	Relevant Hydrographic Stations		
		Site ID	Site Name	Adequacy of Gauge (pers comm. Leon Tepper – Thiess Tatura)
1	Lake Eildon to Molesworth	405203C	Goulburn River @ Eildon	There is an unstable stage/discharge relationship at this site due to seasonal weed growth along the gauging station reach. This has most impact on flows of <1,000 ML/d. For flows between 1,000 and 4,000 ML/d the uncertainty is better than 8% at 95% confidence limit.
2	Molesworth to Seymour	405201B	Goulburn River @ Trawool	Likely issues with lower flows (<1,000 ML/d). The site relies on a natural channel control giving poor low flow sensitivity and a mildly unstable stage discharge relationship. Low flow gaugings are undertaken 2 km upstream of the site.
3	Seymour to Nagambie	405202B	Goulburn River @ Seymour	The stage/discharge relationship is stable. Flow data uncertainty is better than 4% at 95% confidence level.
4	Goulburn Weir to Shepparton	405259A	Goulburn River @ Goulburn Weir	Flood measurement only >3.5 m. Upon request only.
		405200A	Goulburn River @ Murchison	The conventional method of monitoring flow using a stage discharge relationship is not adequate for this site. The site is subject to hysteresis, different types of loop rating curves occur during each event. Acoustic technology is therefore currently being used to collect flow data. The result is that the uncertainty in flow is now better than 7% at 95% confidence level.
		405204C	Goulburn River @ Shepparton	Since major works on and around the low level rock weir downstream of this site, the low flow data is only reasonable. The site is still stabilising. The flow accuracy is within +5.0 to +7%. The site is subject to hysteresis, different types of loop rating curves occur during each event. Acoustic technology is needed.
5	Shepparton to the Murray River	405276A	Goulburn River @ Loch Garry	Flood site only.
		405232C	Goulburn River @ McCoys Bridge	The low flow data is reasonable with flow accuracy at +5 to +7%. The site is subject to hysteresis, different types of loop rating curves occur during each event. Acoustic technology is needed. The sites accuracy can be questioned once flood flows depart from the main stream upstream of the monitoring site.
Living Murray contribution	Conformance assessed at Reach 5	405232	Goulburn River @ McCoys Bridge	See above.

As well as flow monitoring at the sites listed in Table 23, water quality parameters (including colour, dissolved organic carbon, dissolved reactive phosphorus, electrical conductivity, total Kjeldahl nitrogen, oxidised nitrogen, pH, total phosphorus and turbidity) are measured on a monthly basis at:

- Eildon (site 405203)
- Trawool (site 405210)
- Seymour (site 405202)
- Goulburn Weir (site 405259)
- Murchison (site 405200)
- Shepparton (site 405204)
- McCoys Bridge (site 405232).

In addition, the G-MW undertakes continuous DO monitoring at Goulburn Weir and the GB CMA monitors DO at Shepparton and McCoys Bridge. This allows the GB CMA and G-MW to respond to the onset of low DO conditions by increasing flow delivered to the Lower Goulburn River from Lake Eildon and Goulburn Weir.

Fish populations (including fish larvae) along the Lower Goulburn River are surveyed annually as part of the Murray-Darling Basin Sustainable Rivers Audit (SRA), whilstmacroinvertebrate communities are monitored by EPA Victoria as part of its fixed sites monitoring network and also as part of the SRA (SKM 2007). Vegetation condition on the river bank is assessed as part of the Index of Stream Condition assessment, which adopts the 'habitat hectares' approach that compares species and life forms at randomly selected sites against a benchmark. Index of Stream Condition vegetation assessments are conducted at the top of the bank and provide little consistent information about plants lower down the river bank and in the river channel.

The Victorian Environmental Flows Monitoring and Assessment Program (VEFMAP) monitoring has been established for the Lower Goulburn River to monitor habitat availability and the response of vegetation, fish populations and macroinvertebrate populations to environmental flows. Given that this document is aligned with previous environmental flow recommendations for the Goulburn River, the VEFMAP provides a valuable baseline from which to assess ecosystem response to future environmental flows. Parameters to be monitored are considered further in sections 9.3 and 9.4.

9.2 Operational water delivery monitoring

Monitoring the delivery of environmental water along the Lower Goulburn River can be undertaken using the flow gauging sites previously listed in 9.1. In addition, the Department of Sustainability, Environment, Water, Population and Communities has a pro forma Operational Monitoring Report to capture information related to releases, such as event details, risk management, initial observations and other issues (included at Appendix 4). This information is expected to form input into subsequent delivery plans, as well as any applications for return flow credits.

9.3 Key parameters for monitoring and evaluating ecosystem response

The environmental watering objectives for the Lower Goulburn River (Table 3) seek to:

- Provide suitable in-channel habitat (area of slow, shallow water) for all small bodied fish life stages and for in-channel and littoral vegetation.
- Provide deep water habitat for large-bodied native fish.
- Entrain litter packs available as food/habitat source for macroinvertebrates.
- Maintain water quality suitable for macroinvertebrates.
- Provide snag habitat within the euphotic zone to provide habitat and food source for macroinvertebrates.
- Maintain natural rates of sediment dynamics (erosion and deposition) and natural patterns of geomorphic diversity.
- Increase habitat variability for macroinvertebrates and native fish, and increase habitat quality by maintaining or improving water quality (including in pools) and mobilising fine particulate matter.
- Achieve phytoplankton, periphyton and macrophyte production rates, biomass levels and community composition more resembling un-impacted sites to support dynamic, diverse food webs.

VEFMAP monitoring established for the Lower Goulburn River (SKM 2007) includes:

- Physical habitat surveys - river cross sections, qualitative estimate of habitat area and velocity, visual estimate of substratum composition, woody debris load assessment.
- Water quality assessment - monthly in-situ physico-chemical water quality monitoring.
- Riparian and in-channel vegetation surveys.
- Adult fish surveys.
- Macroinvertebrate surveys.

VEFMAP provides information that can be used to assess future environmental flow releases, including that achieved with the delivery of environmental water. Current monitoring undertaken as part of VEFMAP for the Goulburn River, including flow components, hypotheses and indicators, is summarised in Appendix 5.

9.4 Potential monitoring gaps

VEFMAP was established to assess ecosystem responses to changes in watering regimes over time (e.g. five years). It was not designed to assess ecosystem responses to individual or short-term flow events. The main issue for assessing the effectiveness of environmental water (in isolation) is to establish a study design that provides the best possible inference that ecosystem response is due to any particular environmental release(s). Particular attention is required on establishing the 'before' conditions to allow 'before-after' comparisons. Appropriate experimental designs are best considered once the type for flow release(s) is determined (e.g. baseflow, fresh, overbank flow). Monitoring considerations when planning to deliver environmental water are summarised in Table 24 (see also Appendix 5 for references to VEFMAP).

Table 24: Monitoring considerations for the delivery of environmental water.

Asset/ ecosystemattribute	Objective	Existing monitoring	Additional monitoring required
Aquatic and riparian vegetation	Enhance the extent and diversity of aquatic vegetation (in-channel and wetlands). Increased contribution to processes such as river productivity. Maintain diversity of riverbank vegetation. Reduce extent and impact of weeds. Maintain continuity and cover of riverbank vegetation. Enhance the extent and diversity of aquatic vegetation.	VEFMAP frequency will not be sufficient to detect changes in response to individual watering events.	Frequency and timing of monitoring to coincide with individual watering events to assess the effect of its environmental water in isolation from the wider water regime.
Macroinvertebrates	Trophic structure and diversity with a more balanced representation of all functional groups. Ausrivas O/E scores = Band A. Biomass equivalent to rivers elsewhere (e.g. Ovens). Maintain dynamic, diverse food webs that support higher organisms and contribute to river health.	As above.	As above.
Native fish	Suitable in-channel habitat for all life stages. Suitable off-channel habitat for all life stages. Passage for all life stages. Cues for adult migration during spawning season. Access to floodplain and off-channel habitats for spawning and/or larval rearing. Low flows recruitment and survival. Floodplain and bench inundation for exchange of food and organic material between floodplain and channel.	As above.	As above.
Geomorphology	Maintain natural rates of sediment dynamics (erosion and deposition) and natural patterns of geomorphic diversity.	Existing monitoring is appropriate for larger channel-forming events (i.e. approaching bankfull discharge).	Additional monitoring can be considered to evaluate sediment movement and pool depth for smaller flow freshes.
Phytoplankton, periphyton and macrophyte production	Phytoplankton, periphyton and macrophyte production rates, biomass levels and community composition more resembling un-impacted sites to support dynamic, diverse food webs.	None.	Additional monitoring is required.

10. Opportunities

The GB CMA is investigating options to use the volume stored in Goulburn Weir to release flows to coincide with natural flow peaks along the Broken River, thereby providing enhanced flows in the Lower Goulburn River downstream of Shepparton. The volume released from Goulburn Weir would then require some supplementing from Lake Eildon releases. This would involve some operational adjustments, such as managing deliveries along the irrigation channels supplied from Goulburn Weir. This is currently being considered by the GB CMA, but may only be feasible during winter. If the use of Goulburn Weir is not possible, opportunities to deliver the desired summer to autumn fresh on the back of inter-valley transfers should be further explored with G-MW.

There are a number of breaks in the levee system along the Lower Goulburn River, which means that at 40,000 ML/d, approximately 15 per cent of the water goes to the Deep Creek system and then the Murray River. The GB CMA is considering putting regulators on these breaks to keep more water on the floodplain between the river channel and the levees. Regulating structures are also being considered for the Loch Garry system. These are some areas of vegetated floodplain below Loch Garry that could be watered, and this would also help with operating the river more efficiently. Both these opportunities are being considered by the CMA (G. Earl, GB CMA, pers. comm. 2011).

Water from the Goulburn River can also be used to supplement flows to assets on the Murray River downstream. Coordinating the use of environmental water with other releases in the Murray River is an area to be considered once watering options plans for Murray River assets have been prepared.

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Appendix 1: Key species and communities

Key species in the Lower Goulburn River.

Scientific name	Common name	EPBC Status	Presence*	Migratory	FFG listing **
Plants					
Amphibromus fluitans	River swamp wallaby grass	V	May		-
Aristida jerichoensis var. subspinulifera	Jericho wire-grass	-	Known		L
Brachyscome muelleroides	Mueller Daisy	V	Likely		L
Callitriche cyclocarpa	Western water-starwort	V	Known		L
Craspedia canens	Grey billy-buttons	-			L
Cullen parvum	Native scurf-pea	-	Known		L
Myriophyllum porcatum	Ridged water-milfoil	V	Likely		L
Sclerolaena napiformis	Turnip Copperbur	E	Likely		L
Swainsona murrayana	Slender Darling-pea	V	Likely		L
Invertebrate					
Synemon plana	Golden sun month	CE	May		L
Fish					
Bidyanus bidyanus	Silver perch	-	Known	-	L
Craterocephalus fluviatilis	Murray Hardyhead	V	May	-	L
Maccullochella macquariensis	Trout cod	E	Known	-	L
Maccullochella peelii peelii	Murray cod	V	Known	-	L
Macquaria australasica	Macquarie Perch	E	May	-	L
Melanotaenia fluviatilis	Murray-Darling rainbow fish	-	Known	-	L
Tandanus tandanus	Freshwater catfish	-	Known	-	L
Amphibians					
Litoria raniformis	Southern bell or growling grass frog	V	Known		L

Scientific name	Common name	EPBC Status	Presence*	Migratory	FFG listing **
Pseudophryne bibronii	Brown toadlet	-	Known		L
Reptiles					
Aprasia parapulchella	Pink-tailed worm lizard	V	Likely		L
Delma impar	Striped legless lizard	V	Likely		L
Varanus varius	Lace goanna	-			L
Birds					
Anseranas semipalmata	Magpie goose				L
Anthochaera Phrygia *(Xanthomyza Phrygia)*	Regent honeyeater	E	May	Terrestrial, wetlands	L
Apus pacificus	Fork-tailed swift	-	May	Marine	-
Ardea alba	Great egret	-	May	Marine, wetlands	L
Ardea ibis	Cattle egret	-	May	Marine, wetlands	-
Botaurus poiciloptilus	Australasian bittern	E	Known		L
Botaurus poiciloptilus	Australasian bittern	E	Known		
Burhinus grallarius	Bush stone curlew	-	Known		L
Chthonicola sagittata	Speckled warbler	-	Known		
Gallinago hardwickii	Latham's snipe	-	Known	Wetlands	-
Grantiella picta	Painted honeyeater	-	Known		L
Grus rubicunda	Brolga	-	Known		L
Haliaeetus leucogaster	White-bellied sea-eagle	-	Likely	Terrestrial	L
Hirundapus caudacutus	White-throated needletail	-	May	Terrestrial	-
Lathamus discolor	Swift parrot	E	Likely		L
Merops ornatus	Rainbow bee-eater	-	May	Terrestrial	-
Neophema pulchella	Turquoise parrot	-	Known		L
Ninox connivens connivens	Barking owl	-	Known		L
Ninox strenua	Powerful owl	-	Known		L
Pedionomus torquatus	Plains wanderer	V	May		L
Polytelis swainsonii	Superb parrot	V	May		L

Scientific name	Common name	EPBC Status	Presence*	Migratory	FFG listing **
Rostratula australis	Australian painted snipe	V	May		L
Stictonetta naevosa	Freckled duck	-	Known		L
Tyto novaehollandiae novaehollandiae	Masked owl	-	Known		L
Mammals					
Petaurus norfolcensis	Squirrel glider	-	Known		L
Dasyurus maculatus maculatus	Spot-tailed quoll	V	May		L
Phascogale tapoatafa	Brush-tailed phascogale	-	Known		L

E Endangered

CE Critically endangered

L Listed (threatened)

V Vulnerable

The presence of species has been ascertained through:

* EPBC Act, Protected Matters Search Tool website
Department of Sustainability and Environment, Biodiversity Interactive Map website
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Wetland ecological vegetation classes recorded along the lower Goulburn floodplain (DSE 2011).

	EVC	EVC name (32 in total)	Inundated EVC area (ha)			Bioregional conservation status		Targeted for Watering	Flood dependent EVC group names (13 in total)	Note
			Murray Fans	Victorian Riverina	Total	Murray Fans	Victorian Riverina			
Wetland EVCs	992	Water body – Fresh	734.9	384.6	1,119.5	N/A – no vegetation	N/A – no vegetation	No – No Native vegetation recorded (also no EVC template)	–	1
	168	Drainage-line Aggregate	394.3	28.8	423.1	Vulnerable	Endangered	Yes	Drainage-line Aggregate	–
	1022	Drainage-line Aggregate / Riverine Swamp Forest Mosaic	21.4	2.0	23.5	Vulnerable	Endangered	Yes		–
	334	Billabong Wetland Aggregate	355.2	61.4	416.6	Depleted	Vulnerable	Yes	Billabong Wetland Aggregate	–
	172	Foodplain Wetland Aggregate	69.0	87.1	156.1	Depleted	Vulnerable	Yes	Floodplain Wetland Aggregate	–
	804	Rushy Riverine Swamp	51.6	88.0	139.6	Depleted	Depleted	Yes	Rushy Riverine Swamp	–
	1090	Tall Marsh / Open Water Mosaic	–	120.4	120.4	Least concern	Depleted	Yes	Tall Marsh / Open Water Mosaic	–
	1081	Spike-sedge Wetland / Tall Marsh Mosiac	–	49.7	49.7	Vulnerable	Vulnerable	Yes	Spike-sedge Wetland / Tall Marsh Mosaic	–
	810	Floodway Pond Herbland	–	0.4	0.4	Depleted	Vulnerable	Yes	Floodway Pond Herbland	–
	74	Wetland Formation	–	4.3	4.3	Endangered	Endangered	No – Major extent is outside the maximum floodplain inundation area (i.e. 60,000 ML/d inundation	–	–
	125	Plains Grassy Wetland	–	0.2	0.2	Endangered	Endangered	No – Major extent is outside the maximum floodplain inundation area (i.e. 60,000 ML/d inundation	–	–

	EVC	EVC name (32 in total)	Inundated EVC area (ha)			Bioregional conservation status		Targeted for Watering	Flood dependent EVC group names (13 in total)	Note
			Murray Fans	Victorian Riverina	Total	Murray Fans	Victorian Riverina			
Floodplain EVCs	295	Riverine Grassy Woodland	3,898.8	2,163.9	6,062.7	Vulnerable	Vulnerable	Yes	Riverine Grassy Woodland	–
	871	Riverine Grassy Woodland / Plains Woodland / Gilgai Wetland Complex	15.0	–	15.0	Depleted	N/A – not present	Yes		–
	1040	Riverine Grassy Woodland / Riverine Swampy Woodland Mosaic	9.1	6.8	15.9	Vulnerable	Endangered	Yes		–
	56	Floodplain Riparian Woodland	2,011.9	1,143.1	3,156.2	Depleted	Vulnerable	Yes	Floodplain Riparian Woodland	1
	1035	Floodplain Riparian Woodland / Sedgy Riverine Forest Mosaic	–	48.8	48.8	Depleted	Vulnerable	Yes		–
	816	Sedgy Riverine Forest	1,471.4	2,073.9	3,545.4	Depleted	Vulnerable	Yes	Sedgey Riverine Forest	–
	815	Riverine Swampy Woodland	857.0	487.1	1,344.1	Vulnerable	Vulnerable	Yes	Riverine Swampy Woodland	–
	814	Riverine Swamp Forest	250.0	453.4	703.4	Depleted	Depleted	Yes	Riverine Swamp Forest	–
	1099	Riverine Swampy Woodland / Plains Grassy Wetland Mosaic	55.9	–	55.9	Endangered	N/A – not present	Yes		–
	1068	Riverine Swamp Forest / Sedgy Riverine Forest Mosaic	68.8	4.7	73.5	Depleted	Vulnerable	Yes		–
	68	Creekline Grassy Woodland	–	109.4	109.4	Endangered	Endangered	Yes	Creekline Grassy Woodland	–
	106	Grassy Riverine Forest	21.3	–	21.3	Depleted	Depleted	No – Major extent is outside the maximum floodplain inundation area (i.e. 60,000 ML/d inundation	–	–
	823	Lignum Swampy Woodland	0.1	–	0.1	Vulnerable	Vulnerable	No – Major extent is outside the maximum floodplain inundation area (i.e. 60,000 ML/d inundation	–	–

	EVC	EVC name (32 in total)	Inundated EVC area (ha)			Bioregional conservation status		Targeted for Watering	Flood dependent EVC group names (13 in total)	Note
			Murray Fans	Victorian Riverina	Total	Murray Fans	Victorian Riverina			
Terrestrial EVCs	803	Plains Woodland	2,059.1	194.6	2,253.7	Endangered	Endangered	No – EVC is not flood dependent	–	–
	103	Riverine Chenopod Woodland	276.2	–	276.2	Endangered	Endangered	No – EVC is not flood dependent	–	–
	264	Sand Ridge Woodland	91.6	71.4	163.0	Endangered	Endangered	No – EVC is not flood dependent	–	–
	55	Plains Grassy Woodland	–	57.6	57.6	Endangered	Endangered	No – EVC is not flood dependent	–	–
	66	Low Rises Woodland	4.0	9.6	13.6	Endangered	Vulnerable	No – EVC is not flood dependent	–	–
	985	Sandy Beach	–	4.9	4.9	Endangered	Endangered	No – EVC is not flood dependent	–	–
	267	Plains Grassland / Plains Grassy Woodland / Gilgai Wetland Mosaic	1.3	–	1.3	Endangered	Endangered	No – EVC is not flood dependent	–	–
	882	Shallow Sands Woodland	1.0	–	1.0	Vulnerable	Endangered	No – EVC is not flood dependent	–	–

Appendix 2: Flow Recommendations for Reaches 4 & 5

The following provides the flow recommendations outlined in Cottingham et al (2007).

Flow duration bounds identified for Reach 4 ecological objectives.

Note: The values in the table represent the proportion of time that discharge may exceed a particular bound (e.g. 0.85 = 85%). The various percentile years provide opportunities for inter-annual variability, providing different exceedence levels for extreme dry (10th percentile), dry (30th percentile), median and wet years (70th percentile).

				Recommended					
Ecological Objective	Flow Element Code	Discharge (ML/d)	Minimum	10th percentile year	30th percentile year	median year	70th percentile year	90th percentile year	Maximum
Summer - Lower Bound									
MI4	F003b	540		0.90	0.95	0.95	0.98	0.99	
MI1	F007a	310	0.70	0.80	1.00	1.00			
MI3	F007a	310	0.99	0.99	0.99	0.99	0.99		
MI2	F008b	400	0.90	0.93	0.95	0.98	0.98		
n. fish	F008b	400	0.74	0.95	0.99	0.99	0.99		
n. fish	F007b	500	0.97	0.98	0.99	0.99	0.99		
MI6	F003b	540		0.80	0.90	0.95	0.99	0.99	
MI2	F008c	830	0.70	0.93	0.95	0.98	0.98		
Geo3	F026i	856	0.36	0.71	0.94	1.00	1.00	1.0	1.00
Geo3	F026h	1186	0.11	0.57	0.75	0.88	0.96	1.0	1.00
MI1	F007c	1500		0.10	0.30	0.45	0.75		
MI3	F007c	1500		0.15	0.30	0.40	0.70		
Geo3	F026g	1660		0.30	0.47	0.63	0.74	0.94	1.00
Geo3	F026f	2223		0.11	0.25	0.40	0.60	0.71	1.00
Geo3	F026e	3142		0.01	0.06	0.20	0.43	0.55	0.86
Geo3	F026d	4490				0.05	0.24	0.37	0.64
Geo3	F026c	6590					0.08	0.16	0.42
Geo3	F026b	10700						0.04	0.27

Ecological Objective	Flow Element Code	Discharge (ML/d)	Minimum	10th percentile year	30th percentile year	median year	70th percentile year	90th percentile year	Maximum
			Recommended						
Geo3	F026a	19000							
Summer Upper Bound									
Geo3	F026i	856	0.36	0.71	0.94				
Geo3	F026h	1186	0.11	0.57	0.75	0.88	0.96		
MI1	F007c	1500			0.70	0.90	0.90		
Geo3	F026g	1660	0	0.30	0.47	0.63	0.74	0.94	
Geo3	F026f	2223	0	0.11	0.25	0.40	0.60	0.71	
Geo3	F026e	3142	0	0.01	0.06	0.20	0.43	0.55	0.86
Geo3	F026d	4490	0	0	0	0.05	0.24	0.37	0.64
Geo3	F026c	6590	0	0	0	0	0.08	0.16	0.42
Geo3	F026b	10700	0	0	0	0	0	0.04	0.27
Geo3	F026a	19000	0	0	0	0	0	0	0.07
Autumn Lower Bound									
MI2	F008b	400		0.90	0.93	0.95	0.98	0.98	
n. fish	F008b	400		0.99	0.99	0.99	0.99	0.99	
MI4	F003b	540		0.70	0.90	0.95	0.98	0.99	
MI6	F003b	540		0.70	0.90	0.95	0.99	0.99	
MI2	F008c	830		0.50	0.65	0.80	0.95	0.98	
Winter Lower Bound									
n. fish	F008b	400		0.99	0.99	0.99	0.99	0.99	
n. fish	F007b	500		0.80	0.86	0.88	0.90	0.96	
MI4	F003b	540		0.85	0.90	0.95	0.98	0.99	
MI6	F003b	540		0.80	0.90	0.95	0.99	0.99	
MI2	F008c	830		0.90	0.93	0.95	0.98	0.98	

Ecological Objective	Flow Element Code	Discharge (ML/d)	Minimum	Recommended					Maximum
				10th percentile year	30th percentile year	median year	70th percentile year	90th percentile year	
Spring Lower Bound									
n. fish	F008b	400		0.99	0.99	0.99	0.99	0.99	
MI2	F008b	400		0.90	0.93	0.95	0.98	0.98	
n. fish	F008b	400		0.99	0.99	0.99	0.99	0.99	
n. fish	F007b	500		0.81	0.85	0.91	0.95	0.99	
MI4	F003b	540		0.70	0.90	0.95	0.98	0.99	
MI6	F003b	540		0.70	0.90	0.95	0.99	0.99	
MI2	F008c	830		0.90	0.93	0.95	0.98	0.98	
n.fish	F027a	24000				0.05	0.13	0.31	
Spring Upper Bound									
n.fish	F027a	24000		0	0	0.08	0.19	0.47	

Flow duration bounds identified for Reach 5 ecological objectives.

Note: The values represent the proportion of time that discharge may exceed a particular bound (e.g. 0.85 = 85%). The various percentile years provide opportunities for inter-annual variability, providing different exceedence levels for extreme dry (10th percentile), dry (30th percentile), median and wet years (70th percentile).

				Recommended					
Ecological Objective	Flow Element Code	Flow Threshold (ML/d)	Minimum	10th percentile year	30th percentile year	median year	70th percentile year	90th percentile year	Maximum
Summer - Lower Bound									
MI1	F007a	240		0.70	0.80	1.00	1		
MI3	F007a	240		0.99	0.99	0.99	0.99	0.99	
n. fish	F007b	320		0.90	0.90	0.99	0.99	0.99	
MI2	F008b	540		0.90	0.92	0.95	0.98	0.98	
n. fish	F008b	540		0.99	0.99	0.99	0.99	0.99	
MI4	F003b	770		0.90	0.95	0.95	0.98	0.99	
MI6	F003b	770		0.80	0.90	0.95	0.99	0.99	
MI2	F008c	940		0.70	0.92	0.95	0.98	0.98	
Geo3	F026i	1096	0.38	0.75	0.88	0.96	1.00	1.00	1.00
Geo3	F026h	1505	0.17	0.53	0.64	0.82	0.94	1.00	1.00
Geo3	F026g	1993	0.02	0.17	0.40	0.60	0.73	0.97	1.00
Geo3	F026f	2711	0	0.09	0.21	0.35	0.60	0.87	1.00
Geo3	F026e	3800	0	0	0.05	0.20	0.40	0.66	1.00
Geo3	F026d	5240	0	0	0	0.02	0.22	0.43	0.71
Plankt. Algae	F002c	6060				0	0.17		
Geo3	F026c	7560	0	0	0	0	0.08	0.18	0.47
Geo3	F026b	13000	0	0	0	0	0	0.03	0.38
Geo3	F026a	23900	0	0	0	0	0	0	0.09
Summer - Upper Bound									
Geo3	F026i	1096	0.38	0.75	0.88	0.96	1.00	1.00	1.00
Geo3	F026h	1505	0.17	0.53	0.64	0.82	0.94	1.00	1.00

					Recommended				
Ecological Objective	Flow Element Code	Flow Threshold (ML/d)	Minimum	10th percentile year	30th percentile year	median year	70th percentile year	90th percentile year	Maximum
Geo3	F026g	1993	0.02	0.17	0.4	0.60	0.73	0.97	1.00
Geo3	F026f	2711	0	0.09	0.21	0.35	0.60	0.87	1.00
Geo3	F026e	3800	0	0	0.05	0.20	0.40	0.66	1.00
Geo3	F026d	5240	0	0	0	0.02	0.22	0.43	0.71
MI2	F004c	5610		0.01	0.01	0.02	0.30	0.50	
MI4	F004c	5610		0.01	0.01	0.02	0.25	0.45	
Plankt. algae	F002c	6060					0.19	0.30	
Geo3	F026c	7560	0	0	0	0	0.08	0.18	0.47
MI2	F002b	8910		0.01	0.01	0.01	0.05	0.15	
Geo3	F026b	13000	0	0	0	0	0	0.03	0.38
Geo3	F026a	23900	0	0	0	0	0	0	0.09
Autumn - Lower Bound									
n. fish	F007b	320		0.99	0.99	0.99	0.99	0.99	
MI2	F008b	540		0.90	0.92	0.95	0.98	0.98	
n. fish	F008b	540		0.99	0.99	0.99	0.99	0.99	
MI4	F003b	770		0.70	0.90	0.95	0.98	0.99	
MI6	F003b	770		0.70	0.90	0.95	0.99	0.99	
MI2	F008c	940		0.50	0.65	0.80	0.95	0.98	
Autumn - Upper Bound									
MI2	F004c	5610		0.01	0.01	0.02	0.30	0.60	
MI4	F004c	5610					0.03	0.10	
MI2	F002b	8910		0.01	0.01	0.01	0.01	0.05	
Winter - Lower Bound									
n. fish	F007b	320		0.99	0.99	0.99	0.99	0.99	
n. fish	F008b	540		0.99	0.99	0.99	0.99	0.99	

				Recommended					
Ecological Objective	Flow Element Code	Flow Threshold (ML/d)	Minimum	10th percentile year	30th percentile year	median year	70th percentile year	90th percentile year	Maximum
MI4	F003b	770		0.85	0.9	0.95	0.98	0.99	
MI6	F003b	770		0.8	0.9	0.95	0.99	0.99	
MI2	F008c	940		0.9	0.92	0.95	0.98	0.98	
Winter - Upper Bound									
MI2	F002b	8910		0.2	0.3	0.65	0.8	0.9	
Spring - Lower Bound									
n. fish	F007b	320		0.99	0.99	0.99	0.99	0.99	
MI2	F008b	540		0.9	0.92	0.95	0.98	0.98	
n. fish	F008b	540		0.99	0.99	0.99	0.99	0.99	
n. fish	F008b	540		0.99	0.99	0.99	0.99	0.99	
MI4	F003b	770		0.70	0.90	0.95	0.98	0.99	
MI6	F003b	770		0.70	0.90	0.95	0.99	0.99	
MI2	F008c	940		0.90	0.92	0.95	0.98	0.98	
Plankt. algae	F002c	6060							
Spring - Upper Bound									
MI4	F004c	5610		0.42	0.70	0.85	0.95	1.00	
Plankt. algae	F002c	6060		0.35	0.66	0.73	0.86	1.00	
MI2	F002b	8910		0.10	0.40	0.65	0.80	1.00	
n. fish	F027a	24000		0	0.05	0.13	0.26	0.54	

Flow stressors and their components

Code	Description	Elements
F001	Mean hydraulic residence time (hours/km)	-
F002	Proportion of time when euphotic depth is less than *n* times the mean depth	*n* = 0.2, 0.25, 0.3
F003	Proportion of time when mean shear stress is less than *n* N/m^2 - leading to deposition of fine sediments	*n* = 1, 2, 3
F004	Proportion of time when mean shear stress is more than *n* N/m^2 – leading to possibly biofilm instability	*n* = 5, 6, 7
F005	Water level fluctuation characterised by the amphibious habitat index calculated at euphotic depth for the *n*% exceedence flows (in the pre-regulation regime)	*n* = 10, 20, 30, …, 90
F006	Maximum inundation duration at heights up the bank corresponding to the water surface levels for the *n*% exceedence flows (in the pre-regulation regime)	*n* = 10, 20, 30, …, 90
F007	Proportion of time when there is less than *n* m^2/m slow shallow habitat (d<0.5 m, v<0.05 m/s).	*n* = 1, 2, 3, …, 5
F008	Proportion of time when there is less than *n* m^2/m deep water habitat defined as d>1.5 m	*n* = 5, 10, 15, 20
F009	Maximum continuous rise in stage (m)	-
F010	The distribution of daily change in stage characterised by the n^{th} per centile values (m)	*n* = 10, 90
F011	Mean illuminated volume of water (m^3 per m length of channel)	-
F012	Mean ratio of euphotic depth to mean water depth	-
F013	Mean ratio offall velocity (*n* m/s) to mean water depth	*n* = 0.2, 0.4 and 0.94
F014	Mean illuminated area of benthos (m^2 per m length of channel)	-
F015	Mean illuminated area of benthos with velocity less than *n* m/s (m^2 per m length of channel)	*n* = 0.2, 0.3, 0.4 and 0.9
F016	Proportion of time when benthos has been in euphotic zone for at least *n* days, calculated for water surface levels corresponding to the *m*% exceedence flows (in the pre-regulation regime)	*n* = 14 and 42 *m* = 10, 20, 30, …, 90
F017	Number of independent events when benthos has been in euphotic zone for at least *n* days, calculated for water surface levels corresponding to the *m*% exceedence flows (in the pre-regulation regime)	*n* = 14 and 42 *m* = 10, 20, 30, …, 90
F018	Mean water depth (m) during periods when benthos is in euphotic zone for at least *n* days calculated for water surface levels corresponding to the *m*% exceedence flows (in the pre-regulation regime)	*n* = 14 and 42 *m* = 10, 20, 30, …, 90
F019	Proportion of time benthos is in the euphotic zone, calculated for water surface levels corresponding to the *m*% exceedence flows (in the pre-regulation regime)	*m* = 10, 20, 30, …, 90
F020	Proportion of time benthos is below the euphotic zone, calculated for water surface levels corresponding to the *m*% exceedence flows (in the pre-regulation regime)	*m* = 10, 20, 30, …, 90

Code	Description	Elements
F021	Number of overbank events	
F022	The distribution of daily rises in stage characterised by the n^{th} per centile values (m)	n = 10, 90
F023	The distribution of daily falls in stage characterised by the n^{th} per centile values (m)	n = 10, 90
F024	The distribution of daily falls in stage characterised by the n^{th} per centile values (m) for flow bands defined by the flows Qi ML/d	n = 10, 50, 90 = 0, 4000, 100000
F025	Proportion of time water level is within a range defined by water surface levels corresponding to the *m*% exceedence flows (in the pre-regulation regime)	m = 10, 20, 30, …, 90
F026	Proportion of time water level is above a specified depth above bed corresponding to the*m*% exceedence flows (in the pre-regulation regime)	m = 10, 20, 30, …, 90
F027	Proportion of time flow exceeds24,000 Ml/d	

Summary of relationships between flow-related objectives and flow stressors

Ecological Value	Attribute/objective code	Ecological Objective	Stressor code(s)	Seasons	Stressor mechanism
Source of food for fish and invertebrates and influence on river nutrient and chemical conditions.	Planktonic algae	Production rates, biomass levels and community composition more resembling un-impacted sites and dynamic diverse food webs.	F001	Su, Sp	Increased channel retention due to reduced water velocity and/or hydraulic retention zones allows accumulation of biomass if growth rates exceed loss rates.
			F002	Su, Sp	Proportion of time planktonic algae spend in the euphotic zone determines whether net production is possible or not.
			F012	Sp	Proportion of time planktonic algae spend in the euphotic zone multiplied by mean surface irradiance determines the relative level of production.
			F013	Su, Sp	Water depth influences the rate of deposition of planktonic algae (It takes longer for settling in deeper water).
Source of food for fish and invertebrates, habitat, and influence on river nutrient and chemical conditions.	Periphytic algae	Production rates, biomass levels and community composition more resembling un-impacted sites and dynamic diverse food webs.	F014	Su, Sp	Benthic production is restricted to wetted perimeter within the euphotic zone (i.e. where light penetrates to the channel bed and banks).
			F015	Su, Sp	High velocities influencing biofilm stability. Area of colonization determined by extent of light zone - use euphotic depth, but limited by velocity.
			F016	Sp	Establishment of biofilm requires that the wetted surface remains wet and within the euphotic depth for a period of some time. Drying and submersion below the euphotic depth will adversely affect biofilm.
Contributes to primary production, habitat for macroinvertebrates and native fish.	Macrophytes	Production rates, biomass levels and community composition more resembling un-impacted sites and dynamic diverse food webs.	F014	Su, Au, Wi, Sp	Benthic production is restricted to wetted perimeter within the euphotic zone (i.e. where light penetrates to the channel bed and banks).
			F015	Su, Au, Sp	High velocities influencing biofilm stability. Area of colonization determined by extent of light zone - use euphotic depth, but limited by velocity.
			F016	Su, Au, Sp	Establishment of aquatic macrophytes requires that the wetted surface remains wet and within the euphotic depth for a period of some time. Drying and submersion below the euphotic depth will adversely affect macrophytes.
Natural gradient of native terrestrial vegetation up the river banks.	Terrestrial bank vegetation	Maintain native terrestrial cover at top of banks and reduce cover of terrestrial vegetation in areas of the bank influenced by flow regulation.	F006	Dec-Apr	Duration of submergence (inundation) has potential to drown out terrestrial vegetation, due to carbon and oxygen starvation; critical values for duration tolerance expected to vary between seasons, being much longer in cool (autumn-winter) than in warm growing (spring-summer) season.

Ecological Value	Attribute/objective code	Ecological Objective	Stressor code(s)	Seasons	Stressor mechanism
Diverse and resilient aquatic macroinvertebrate fauna that are an integral part of food webs.	MI1	Provision of conditions suitable for aquatic vegetation, which provides habitat for macroinvertebrates.	F007	Su	Slow shallow velocities required for establishment of aquatic vegetation.
			F010	Wi	Short-term flow fluctuations can adversely affect aquatic vegetation growing along the channel margins.
			F022	Su, Au, Wi, Sp	Short-term flow fluctuations can adversely affect aquatic vegetation growing along the channel margins.
			F023	Su, Au, Wi, Sp	Short-term flow fluctuations can adversely affect aquatic vegetation growing along the channel margins.
	MI2	Submersion of snag habitat within the euphotic zone to provide habitat and food source for macroinvertebrates.	F002	Su, Au, Wi, Sp	Quantity and variety of snags dependent on volume (possibly modified by biodiversity and productivity of snag biofilm - depth and variability of light climate).
			F004	Su, Au	High shear stresses can lead to biofilm instability.
			F008	Su, Au, Wi, Sp	Loss of pools.
			F025	Dec-Apr	Reduction in flow result in drying of large woody debris.
	MI3	Provision of slackwater habitat favourable for planktonic production (food source) and habitat for macroinvertebrates (MI3).	F007	Su	Increased flow velocity and rapid rates of rise and fall affect availability of shallow, slackwater habitat for macroinvertebrates.
			F023	Su, Au, Wi, Sp	Daily fall in stage.
			F024	Dec-Apr	Daily fall in stage.
	MI4	Entrainment of litter packs available as food/habitat source for macroinvertebrates (MI4).	F003	Su, Au, Wi, Sp	Shear stress required to disrupt (refresh) biofilms and entrain organic matter.
			F004	Su, Au, Sp	Shear stress required to disrupt (refresh) biofilms and entrain organic matter.
			F021	Su, Au, Wi, Sp	Overbank events may entrain organic matter
	MI6	Maintenance of water quality suitable for macroinvertebrates.	F003	Su, Au, Wi, Sp	Temperature, nutrients and salinity assumed not significant, pollution effects (toxicants) not known. Sediment deposition noted and known to remove susceptible taxa.

Ecological Value	Attribute/objective code	Ecological Objective	Stressor code(s)	Seasons	Stressor mechanism
Diversity of native species, naturally self-reproducing populations of native fish, threatened and iconic native species.	Native Fish	Suitable in-channel habitat for all life stages.	F007	Su, Aut, Wi, Sp	Slow shallow habitat required for larvae/juvenile recruitment and adult habitat for small bodied fish.
			F008	Su, Au, Wi, Sp	Deep water habitat for large bodied fish.
		Cues for adult migration during spawning season.	F022	Su, Sp	Flow variation required as a cue for migration and spawning.
			F023	Su, Sp	Flow variation required as a cue for migration and spawning.
		Suitable off-channel habitat for all life stages.	F027	Sp	Inundation of floodplain required by some species and for transport of nutrients and organic matter to drive food webs.
Natural Channel Form and Dynamics.	Geo1	Avoid notching.	F025	Dec-Apr	Long duration of stable flow followed by rapid draw-down. Impact likely to be exacerbated by loss of bank side vegetation.
	Geo2	Avoid slumping.	F023	Su	Excessive rates of fall in river level.
	Geo3	Maintain pool depth.	F026	Su	Unseasonal events that fill pools with sediment but do not flush them.
	Geo6	Maintain natural rates of geomorphic disturbance.	F006	Dec-Apr	High velocity discharge increases disturbance of sand substrates and aquatic macrophytes.

13.

Appendix 3: Monthly environmental water demand shortfalls

Additional volumes required to meet baseflow targets related to ecosystem objectives for Reach 4 of the Lower Goulburn River – extreme dry (high reliability water share allocation of 70% or less).

Flow target	310 ML/d		400 ML/d		500 ML/d		540 ML/d		610 ML/d		830 ML/d		860 ML/d	
Modelled shortfall in meeting flow target (GL)														
Month	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max
January	0.0	0.0	0.0	0.0	n/a	n/a	n/a	n/a	0.0	5.4	n/a	n/a	n/a	n/a
February	0.0	0.0	0.0	2.1	n/a	n/a	n/a	n/a	4.0	8.6	n/a	n/a	n/a	n/a
March	0.0	0.0	0.0	0.1	n/a	n/a	n/a	n/a	5.1	6.0	n/a	n/a	n/a	n/a
April	0.0	0.0	0.0	0.5	n/a	n/a	n/a	n/a	4.2	7.0	n/a	n/a	n/a	n/a
May	0.0	0.0	0.0	1.9	n/a	n/a	n/a	n/a	4.7	8.2	n/a	n/a	n/a	n/a
June	0.0	0.4	0.0	3.2	n/a	n/a	n/a	n/a	0.0	9.7	n/a	n/a	n/a	n/a
July	0.0	0.0	0.0	2.1	n/a	n/a	n/a	n/a	0.0	8.4	n/a	n/a	n/a	n/a
August	0.0	0.0	0.0	0.0	n/a	n/a	n/a	n/a	0.0	6.3	n/a	n/a	n/a	n/a
September	0.0	0.0	0.0	0.0	n/a	n/a	n/a	n/a	0.0	6.0	n/a	n/a	n/a	n/a
October	0.0	0.0	0.0	0.0	n/a	n/a	n/a	n/a	1.4	2.7	n/a	n/a	n/a	n/a
November	0.0	0.0	0.0	0.0	n/a	n/a	n/a	n/a	0.0	3.0	n/a	n/a	n/a	n/a
December	0.0	0.0	0.0	0.0	n/a	n/a	n/a	n/a	0.0	0.0	n/a	n/a	n/a	n/a

Additional volumes required to meet baseflow targets related to ecosystem objectives for Reach 4 of the Lower Goulburn River – dry (100% high reliability water share allocation, and low reliability water share allocation of 0-20%).

Flow target	310 ML/d		400 ML/d		500 ML/d		540 ML/d		610 ML/d		830 ML/d		860 ML/d	
Modelled shortfall in meeting flow target (GL)														
Month	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max
January	n/a	n/a	n/a	n/a	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
February	n/a	n/a	n/a	n/a	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
March	n/a	n/a	n/a	n/a	0.0	3.4	0.0	4.5	0.0	6.5	0.0	12.9	0.0	13.8
April	n/a	n/a	n/a	n/a	0.0	4.4	0.0	5.6	0.0	7.8	0.0	14.6	0.0	15.5
May	n/a	n/a	n/a	n/a	0.0	5.5	0.0	6.7	0.0	8.8	0.0	15.4	0.0	16.3
June	n/a	n/a	n/a	n/a	0.0	5.4	0.0	6.7	0.0	8.8	0.0	15.6	0.0	16.6
July	n/a	n/a	n/a	n/a	0.0	5.1	0.0	6.3	0.0	8.4	0.0	15.0	0.0	15.9
August	n/a	n/a	n/a	n/a	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
September	n/a	n/a	n/a	n/a	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.2	0.0	2.2
October	n/a	n/a	n/a	n/a	0.0	1.0	0.0	2.2	0.0	4.3	0.0	10.9	0.0	11.8
November	n/a	n/a	n/a	n/a	0.0	0.0	0.0	0.2	0.0	2.4	0.0	9.2	0.0	10.2
December	n/a	n/a	n/a	n/a	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Additional volumes required to meet baseflow targets related to ecosystem objectives for Reach 4 of the Lower Goulburn River – median (100% high reliability water share allocation, and low reliability water share allocation of 21-80%).

Flow target	310 ML/d		400 ML/d		500 ML/d		540 ML/d		610 ML/d		830 ML/d		860 ML/d	
Modelled shortfall in meeting flow target (GL)														
Month	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max
July	n/a	n/a	n/a	n/a	0.0	5.1	0.0	6.3	0.0	8.4	0.0	15.0	0.0	15.9
August	n/a	n/a	n/a	n/a	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
September	n/a	n/a	n/a	n/a	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
October	n/a	n/a	n/a	n/a	0.0	0.0	0.0	0.0	0.0	1.4	0.0	8.0	0.0	8.9
November	n/a	n/a	n/a	n/a	0.0	0.0	0.0	0.2	0.0	2.4	0.0	9.2	0.0	10.1
December	n/a	n/a	n/a	n/a	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
January	n/a	n/a	n/a	n/a	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
February	n/a	n/a	n/a	n/a	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
March	n/a	n/a	n/a	n/a	0.0	3.3	0.0	4.4	0.0	6.5	1.2	12.8	2.0	13.7
April	n/a	n/a	n/a	n/a	0.0	3.4	0.0	4.6	0.0	6.8	0.0	13.6	0.0	14.5
May	n/a	n/a	n/a	n/a	0.0	5.4	0.0	6.6	0.0	8.7	0.0	15.3	0.0	16.2
June	n/a	n/a	n/a	n/a	0.0	6.2	0.0	7.4	0.0	9.6	0.0	16.4	0.0	17.3

Additional volumes required to meet baseflow targets related to ecosystem objectives for Reach 4 of the Lower Goulburn River – wet (100% high reliability water share allocation, and low reliability water share allocation of 81-100%).

Flow target	310 ML/d		400 ML/d		500 ML/d		540 ML/d		610 ML/d		830 ML/d		860 ML/d	
Modelled shortfall in meeting flow target (GL)														
Month	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max
July	n/a	n/a	n/a	n/a	0.0	3.8	0.0	5.0	0.0	7.1	0.0	13.7	0.0	14.6
August	n/a	n/a	n/a	n/a	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
September	n/a	n/a	n/a	n/a	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
October	n/a	n/a	n/a	n/a	0.0	0.0	0.0	0.0	0.0	0.0	0.0	6.1	0.0	7.0
November	n/a	n/a	n/a	n/a	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.5	0.0	6.4
December	n/a	n/a	n/a	n/a	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
January	n/a	n/a	n/a	n/a	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
February	n/a	n/a	n/a	n/a	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
March	n/a	n/a	n/a	n/a	0.0	4.8	0.0	6.0	0.0	8.0	0.0	14.4	0.0	15.2
April	n/a	n/a	n/a	n/a	0.0	3.1	0.0	4.3	0.0	6.5	0.0	13.3	0.0	14.2
May	n/a	n/a	n/a	n/a	0.0	5.7	0.0	6.9	0.0	9.0	0.0	15.6	0.0	16.5
June	n/a	n/a	n/a	n/a	0.0	2.5	0.0	3.8	0.0	5.9	0.0	12.7	0.0	13.7

Additional volumes required to meet baseflow targets related to ecosystem objectives for Reach 5 of the Lower Goulburn River – extreme dry (high reliability water share allocation of 70% or less).

Flow target	310 ML/d		400 ML/d		500 ML/d		540 ML/d		610 ML/d		830 ML/d		860 ML/d	
Modelled shortfall in meeting flow target (GL)														
Month	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max
July	0.0	0.0	0.0	0.0	n/a	n/a	n/a	n/a	0.0	5.9	n/a	n/a	n/a	n/a
August	0.0	0.0	0.0	0.0	n/a	n/a	n/a	n/a	0.0	0.1	n/a	n/a	n/a	n/a
September	0.0	0.0	0.0	0.0	n/a	n/a	n/a	n/a	0.0	3.5	n/a	n/a	n/a	n/a
October	0.0	0.0	0.0	0.0	n/a	n/a	n/a	n/a	0.9	4.5	n/a	n/a	n/a	n/a
November	0.0	0.0	0.0	0.0	n/a	n/a	n/a	n/a	1.2	2.1	n/a	n/a	n/a	n/a
December	0.0	0.0	0.0	0.0	n/a	n/a	n/a	n/a	0.0	0.0	n/a	n/a	n/a	n/a
January	0.0	0.0	0.0	0.0	n/a	n/a	n/a	n/a	0.0	4.9	n/a	n/a	n/a	n/a
February	0.0	0.0	0.0	1.4	n/a	n/a	n/a	n/a	4.9	7.9	n/a	n/a	n/a	n/a
March	0.0	0.0	0.0	0.0	n/a	n/a	n/a	n/a	4.5	5.3	n/a	n/a	n/a	n/a
April	0.0	0.0	0.0	0.0	n/a	n/a	n/a	n/a	3.4	6.2	n/a	n/a	n/a	n/a
May	0.0	0.0	0.0	1.2	n/a	n/a	n/a	n/a	4.0	7.5	n/a	n/a	n/a	n/a
June	0.0	0.0	0.0	1.9	n/a	n/a	n/a	n/a	0.0	8.4	n/a	n/a	n/a	n/a

Additional volumes required to meet baseflow targets related to ecosystem objectives for Reach 5 of the Lower Goulburn River – dry (100% high reliability water share allocation, and low reliability water share allocation of 0-20%).

Flow target	310 ML/d		400 ML/d		500 ML/d		540 ML/d		610 ML/d		830 ML/d		860 ML/d	
Modelled shortfall in meeting flow target (GL)														
Month	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max
July	n/a	n/a	n/a	n/a	0.0	1.4	0.0	2.6	0.0	4.7	0.0	11.3	0.0	12.2
August	n/a	n/a	n/a	n/a	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
September	n/a	n/a	n/a	n/a	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
October	n/a	n/a	n/a	n/a	0.0	0.0	0.0	0.6	0.0	2.7	0.0	9.3	0.0	10.2
November	n/a	n/a	n/a	n/a	0.0	0.0	0.0	0.0	0.0	2.1	0.0	8.9	0.0	9.8
December	n/a	n/a	n/a	n/a	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
January	n/a	n/a	n/a	n/a	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
February	n/a	n/a	n/a	n/a	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
March	n/a	n/a	n/a	n/a	0.0	3.4	0.0	4.5	0.0	6.6	0.0	12.9	0.0	13.8
April	n/a	n/a	n/a	n/a	0.0	2.4	0.0	3.7	0.0	5.8	0.0	12.6	0.0	13.6
May	n/a	n/a	n/a	n/a	0.0	4.3	0.0	5.5	0.0	7.6	0.0	14.2	0.0	15.1
June	n/a	n/a	n/a	n/a	0.0	2.5	0.0	3.8	0.0	5.9	0.0	12.8	0.0	13.7

Additional volumes required to meet baseflow targets related to ecosystem objectives for Reach 5 of the Lower Goulburn River – median (100% high reliability water share allocation, and low reliability water share allocation of 21-80%).

Flow target	310 ML/d		400 ML/d		500 ML/d		540 ML/d		610 ML/d		830 ML/d		860 ML/d	
Modelled shortfall in meeting flow target (GL)														
Month	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max
July	n/a	n/a	n/a	n/a	0.0	2.2	0.0	3.4	0.0	5.5	0.0	12.1	0.0	13.0
August	n/a	n/a	n/a	n/a	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
September	n/a	n/a	n/a	n/a	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
October	n/a	n/a	n/a	n/a	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.7	0.0	5.6
November	n/a	n/a	n/a	n/a	0.0	0.0	0.0	0.0	0.0	1.2	0.0	8.1	0.0	9.0
December	n/a	n/a	n/a	n/a	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
January	n/a	n/a	n/a	n/a	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
February	n/a	n/a	n/a	n/a	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
March	n/a	n/a	n/a	n/a	0.0	2.8	0.0	3.9	0.0	5.9	0.0	12.1	0.0	12.9
April	n/a	n/a	n/a	n/a	0.0	1.9	0.0	3.1	0.0	5.3	0.0	12.1	0.0	13.0
May	n/a	n/a	n/a	n/a	0.0	4.3	0.0	5.5	0.0	7.6	0.0	14.2	0.0	15.1
June	n/a	n/a	n/a	n/a	0.0	3.3	0.0	4.5	0.0	6.7	0.0	13.5	0.0	14.4

Additional volumes required to meet baseflow targets related to ecosystem objectives for Reach 5 of the Lower Goulburn River – wet (100% high reliability water share allocation, and low reliability water share allocation of 81-100%).

Flow target	310 ML/d		400 ML/d		500 ML/d		540 ML/d		610 ML/d		830 ML/d		860 ML/d	
Modelled shortfall in meeting flow target (GL)														
Month	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max
July	n/a	n/a	n/a	n/a	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.7	0.0	6.6
August	n/a	n/a	n/a	n/a	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
September	n/a	n/a	n/a	n/a	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
October	n/a	n/a	n/a	n/a	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.7
November	n/a	n/a	n/a	n/a	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.5	0.0	6.4
December	n/a	n/a	n/a	n/a	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
January	n/a	n/a	n/a	n/a	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
February	n/a	n/a	n/a	n/a	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
March	n/a	n/a	n/a	n/a	0.0	1.3	0.0	2.5	0.0	4.5	0.0	10.9	0.0	11.8
April	n/a	n/a	n/a	n/a	0.0	0.0	0.0	0.0	0.0	2.0	0.0	8.8	0.0	9.7
May	n/a	n/a	n/a	n/a	0.0	4.3	0.0	5.5	0.0	7.6	0.0	14.2	0.0	15.1
June	n/a	n/a	n/a	n/a	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.0	0.0	4.0

Appendix 4: Operational Monitoring Report

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	**<EWDS to prefill>**	**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) <EWDS to prefill>*	
	Total volume of water allocated for the watering event *CEW:* *Other(please specify) :*	
	Total volume of water delivered in watering event *CEW:* *Other (please specify):*	*Delivery measurement* *Delivery mechanism:* *Method of measurement:* *Measurement location:*
	Delivery start date (and end date if final report) of watering event	
	Please provide details of any complementary works	
	If a deviation has occurred between agreed and actual delivery volumes or delivery arrangements, please provide detail	
	Maximum area inundated (ha) (if final report)	
	Estimated duration of inundation (if known)[1]	
Risk management	*Please describe the measure(s) that were undertaken to mitigate identified risks for the watering event (eg. water quality, alien species); please attach any relevant monitoring data.* *Have any risks eventuated? Did any risk issue(s) arise that had not been identified prior to delivery? Have any additional management steps been taken?*	
Other Issues	*Have any other significant issues been encountered during delivery?*	
Initial Observations	*Please describe and provide details of any species of conservation significance (state or Commonwealth listed threatened species, or listed migratory species) observed at the site during the watering event?*	
	Please describe and provide details of any breeding of frogs, birds or other prominent species observed at the site during the watering event?	
	Please describe and provide details of any observable responses in vegetation, such as improved vigour or significant new growth, following the watering event?	
	Any other observations?	
Photographs	*Please attach photographs of the site prior, during and after delivery*[2]	

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

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

Appendix 5: Summary of VEFMAP monitoring in Reaches 4 and 5 of the Goulburn River

Summary of VEFMAP monitoring arrangements for environmental water use in the Goulburn River (from SKM 2007, Chee et al. 2006).

Flow component	Hypotheses	Indicator(s)	Monitoring sites	Frequency	Considerations for this watering options project
Geomorphology					
Winter/spring freshes	Does increased frequency of winter-spring fresh events: a) Increase the frequency of geomorphologically significant events (e.g. redistribution of bed and bank sediments)? b) IIncrease channel complexity (e.g. areas of the stream bed which are flushed free of fine deposits, deeper pools and variability in bench elevations)? c) IIncrease channel width and depth? d) IIncrease rates of meander development (i.e. bank erosion on the outside bank, point bar development, increased sinuosity and eventually bend cut-off and billabong formation)?	Flow and physical habitat (channel dimensions) to assess: • Frequency of channel disturbances • Frequency of bed disturbances • Rate of bench deposition • Bed complexity • Bench development and variability • Mean channel top width, cross-section area and thalweg depth • Bank erosion on outside of meander bends • Point bar development.	Two physical habitat sites in each of Reach 4 and Reach 5. Three flow sites in Reach 4 and two flow sites in Reach 5.	Physical habitat - first year (2008) and after channel forming events thereafter. Flow – continuous at all sites.	VEFMAP provides baseline information for assessing effects of environmental water. May require repeat measurements to provide 'before' data if channel dimensions have not been surveyed after recent (2010) flood events.
Bankfull and overbank flows	As above	As above	As above	As above	As above

Flow component	Hypotheses	Indicator(s)	Monitoring sites	Frequency	Considerations for this watering options project
Habitat & macroinvertebrates					
Summer/autumn low flows and freshes	• Do implemented environmental flows maintain in-channel shallow and slow water areas? • Do implemented environmental flows maintain adequate area and depth of at least 0.1 metres in shallow, slow water and riffle/run habitats? • Do implemented environmental flows maintain adequate volume and depth in permanent pools? • Do implemented environmental flows maintain connectivity? • Do implemented environmental flows maintain macroinvertebrate community structure? • Do implemented environmental flows increase fish recruitment? • Do implemented environmental flows maintain fish assemblages and/or population structure?	• Shallow and slow water areas • Riffle/run depth and area • Permanent pool depth and volume • Connectivity • Number of invertebrate families index • AUSRIVAS score • SIGNAL biotic index • EPT biotic index • Presence/absence and number of 'flow-sensitive' taxa • See conceptual model for Fish Spawning & Recruitment • Fish species composition • Relative abundance of adult/sub-adult native and exotic fish species • Population structure and size class distribution of native and exotic fish species.	Two physical habitat sites in each of Reach 4 and Reach 5. Four macroinvertebrate sites in Reach 4. No sites in Reach 5. See also native fish monitoring (below).	Physical habitat - first year (2008) and after channel forming events thereafter. Annually	As above VEFMAP sampling was not designed to assess short-term changes. Will require more frequent 'before' and 'after' sampling if the effects of environmental water are to be assessed in isolation.

Flow component	Hypotheses	Indicator(s)	Monitoring sites	Frequency	Considerations for this watering options project
Winter/spring baseflows	• Do implemented environmental flows increase in-channel shallow and slow water areas? • Do implemented environmental flows increase area of riffle and/or run habitat? • Do implemented environmental flows increase volume of permanent pool habitats? • Do implemented environmental flows result in sustained inundation of in-channel macrophytes, channel edge macrophytes, tree roots, woody debris, branch piles, in channel bars, overhanging or undercut banks? • Do implemented environmental flows increase abundance of macrophytes? • Do implemented environmental flows improve macroinvertebrate community structure? • Do implemented environmental flows improve fish assemblages and/or population structure?	• Shallow and slow water areas • Riffle and/or run area • Permanent pool depth and volume • Inundation of representative physical habitat features • See conceptual model for Aquatic and Riparian Vegetation • Cover of submerged and amphibious species • Cover of submerged and amphibious species • Number of invertebrate families index • AUSRIVAS score • SIGNAL biotic index • EPT biotic index • Presence/absence and number of 'flow-sensitive' taxa • Fish species composition • Relative abundance of adult/sub-adult native and exotic fish species • Population structure and size class distribution of native and exotic fish species.	Two physical habitat sites in each of Reach 4 and Reach 5. Four macroinvertebrate sites in Reach 4. No sites in Reach 5. See also native fish monitoring (below).	Annually	As above VEFMAP sampling was not designed to assess short-term changes. Will require more frequent 'before' and 'after' sampling if the effects of environmental water are to be assessed in isolation.

Flow component	Hypotheses	Indicator(s)	Monitoring sites	Frequency	Considerations for this watering options project
Winter/spring freshes	• Do implemented environmental flows increase area of riffle and/or run habitat? • Do implemented environmental flows increase volume of pool habitats? • Do implemented environmental flows result in temporary inundation of higher-level channel edge macrophytes, tree roots, woody debris, bars, benches, overhanging/ undercut banks? • Do implemented environmental flows improve macroinvertebrate community structure? • Do implemented environmental flows improve fish assemblages and/ or population structure?	• Riffle and/or run area • Permanent pool depth and volume • Inundation of higher elevation representative physical habitat features • Number of invertebrate families index • AUSRIVAS score • SIGNAL biotic index • EPT biotic index • Presence/absence and number of 'flow-sensitive' taxa • Fish species composition • Relative abundance of adult/ sub-adult native and exotic fish species • Population structure and size class distribution of native and exotic fish species.	Two physical habitat sites in each of Reach 4 and Reach 5. Four macroinvertebrate sites in Reach 4. No sites in Reach 5. See also native fish monitoring (below).	Annually	As above

Flow component	Hypotheses	Indicator(s)	Monitoring sites	Frequency	Considerations for this watering options project
Aquatic & riparian vegetation					
Spring baseflow	• Do implemented environmental flows increase in-channel shallow and slow water areas? • Do implemented environmental flows increase run area? • Do implemented environmental flows result in sustained inundation of channel bed, channel edges, in-channel bars, low-lying benches, runners and anabranches in Zone A*? • Do implemented environmental flows • a) IIncrease germination and seasonal growth of submerged and amphibious fluctuation-responder species in Zone A*? • b) IReduce species richness of terrestrial 'dry' species in Zone A*?	• Shallow and slow water area • Run depth and area • Inundation of geomorphic features in Zone A* • Cover of submerged and amphibious species in Zone A* • Species composition, number of submerged, amphibious and terrestrial species in Zone A* • Proportion of exotic plant species.	Two sites in each of Reach 4 and 5	Every two years	As above
	• What is the pattern of inundation and drying in Zones A* & B* imposed by the implemented environmental flows? • What is the composition of the resultant plant community?	• Cover of amphibious and terrestrial species in Zones A* & B* • Species composition, number of amphibious and terrestrial species in Zones A* & B* • Proportion of exotic plant species	As above	As above	As above

Flow component	Hypotheses	Indicator(s)	Monitoring sites	Frequency	Considerations for this watering options project
Spring freshes & bankfull flows	• Do implemented environmental flows wet high-level benches, upper banks, runners and anabranches in Zones B* & C*? • Do implemented environmental flows increase germination and establishment of terrestrial 'damp', terrestrial 'dry' and amphibious fluctuation-tolerator species? • Do implemented environmental flows improve canopy condition of in situ riparian trees and shrubs?	• Wetting of geomorphic features in Zones B* & C* • Species composition, number of amphibious and terrestrial species in Zones B* & C* • Proportion of exotic plant species • Germination of seedlings of over storey and mid-storey species • Canopy condition.	As above	As above	As above
Summer baseflow	• Do implemented environmental flows maintain area of in-channel shallow and slow water and run habitats? • Do implemented environmental flows wet in-channel bars, low-lying benches, channel edges, runners and anabranches in Zone A*? • Do implemented environmental flows improve canopy condition of adjacent riparian trees and shrubs?	• See conceptual model for Habitat Processes • Shallow and slow water areas • Run depth and area. • Wetting of geomorphic features in Zone A* • Canopy condition.	As above	As above	As above
Native fish					
Autumn-early winter freshes/ bankfull flows	• Do implemented environmental flows trigger spawning of diadromous fish? (Only relevant in river reaches inhabited by diadromous fish species such as galaxiids, eels and Australian grayling)	• Presence/absence of diadromous fish larvae	Six sites in each of Reach 4 and 5	Annually	VEFMAP may be appropriate for considering effects of environmental water, but it may also be difficult to separate from other influences, including recent flow history (i.e. antecedent conditions).

Flow component	Hypotheses	Indicator(s)	Monitoring sites	Frequency	Considerations for this watering options project
Winter-spring baseflows freshes	• Do implemented environmental flows increase overall quantity and diversity of in stream habitat?	• See conceptual model for Habitat Processes • Shallow and slow water areas • Run area • Permanent pool depth and volume • Inundation of physical habitat features • Inundation of higher elevation physical habitat features • In-channel and littoral cover of macrophytes.	As above	As above	As above
Spring-early summer bankfull flows	• Do implemented environmental flows inundate low-lying runners and anabranches to create increased slackwater habitat? • Do implemented environmental flows increase the number of fish completing larval stages?	• Area of slackwater habitat in runners and anabranches • Density of post-larval fish.	As above	As above	As above

Flow component	Hypotheses	Indicator(s)	Monitoring sites	Frequency	Considerations for this watering options project
Spring-early summer base flows	• Do implemented environmental flows provide appropriate conditions for spawning and larval production of 'low flow specialist' and generalist fish species? • Do implemented environmental flows maintain adequate in stream habitat for adult and larval fish? • Do implemented environmental flows increase the number of fish completing larval stages?	• Presence/absence of 'low flow specialist' and generalist fish larvae • See conceptual model for Habitat Processes • Shallow and slow water area • Run area • Permanent pool depth and volume • Connectivity • Density of post-larval fish.	As above	As above	As above
Spring-early summer overbank flows	• Do implemented environmental flows inundate low-lying runners and anabranches to create increased slackwater habitat? • Do implemented environmental flows inundate floodplain areas to create increased slackwater habitat? • Do implemented environmental flows provide appropriate conditions for spawning and larval production of 'flood specialist' non-diadromous fish species? • Do implemented environmental flows increase the number of fish completing larval stages?	• Area of slackwater habitat in runners and anabranches • Area of slackwater habitat in floodplain • Presence/absence of 'flood specialist' non-diadromous fish larvae • Density of post-larval fish.	As above	As above	As above

Flow component	Hypotheses	Indicator(s)	Monitoring sites	Frequency	Considerations for this watering options project
Summer-autumn low flows	• Do implemented environmental flows maintain adequate in stream habitat for adult and larval fish? • Do implemented environmental flows increase the number of fish completing larval stages?	• See conceptual model for Habitat Processes • Shallow and slow water area • Run area • Permanent pool depth and volume • Connectivity • Density of post-larval fish.	As above	As above	As above
Water Quality					
All components (year- round)	• No specific hypotheses	Colour, dissolved organic carbon, dissolved reactive phosphorus, electrical conductivity, total Kjeldahl nitrogen, oxidized nitrogen, pH, total phosphorus and turbidity.	Two sites in each of Reach 4 and 5	As per NERWMP	Dedicated monitoring program may be required, depending on the water quality variable to be tested.

Zone A*:From mid-channel to stream margin (or the area covered by water during times of baseflow).

Zone B*:From stream margin to a point mid-way up the flank of the bank (or the point that is infrequently inundated).

Zone C*:From mid-way up the flank of the bank to just beyond the top of the bank.

Appendix 6: Risk assessment framework

Risk likelihood rating

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

Risk consequence rating

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

Risk analysis matrix

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

Australian Government

Commonwealth Environmental Water

ENVIRONMENTAL WATER DELIVERY

Murrumbidgee Valley

JANUARY 2012 V1.0

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Telephone Bank Wetlands
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River red gums, Yanga National Park
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Sinclair Knight Merz (2011). *Environmental Water Delivery: Murrumbidgee Valley.* Prepared for Commonwealth Environmental Water, Department of Sustainability, Environment, Water, Population and Communities, Canberra.

ISBN: 978-1-921733-28-4

Commonwealth Environmental Water acknowledges the following organisations and individuals who have been consulted in the preparation of this document:

Murray-Darling Basin Authority
Ben Gawne (Murray-Darling Freshwater Research Centre)
Garry Smith (DG Consulting)
Daren Barma (Barma Water Resources)
Jim Parrett (Rural and Environmental Services)
Karen McCann (Murrumbidgee Irrigation)
Rob Kelly
Chris Smith
James Maguire (NSW Office of Environment and Heritage)
Andrew Petroeschevsky (NSW Dept. Primary Industries)
Lorraine Hardwick (NSW Office of Water)
Adam McLean (State Water Corporation)
Eddy Taylor (State Water Corporation)
Arun Tiwari (Coleambally Irrigation Cooperative Limited)
Austen Evans (Coleambally Irrigation Cooperative Limited)

Published by Commonwealth Environmental Water for the Australian Government.

ENVIRONMENTAL WATER DELIVERY

Murrumbidgee Valley

JANUARY 2012 V1.0

Environmental water delivery: Murrumbidgee Valley

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 our consultation process for Commonwealth environmental water we are 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 within the Murrumbidgee Valley. As the first version of the document, it is intended to provide a starting point for discussions on environmental water use. As such, suggestions and feedback on the document are encouraged and will be used to inform planning for environmental water use and future iterations of the document.

The Murrumbidgee Valley supports important ecological values including internationally significant wetlands. Potential water use options for the system include piggybacking on natural flows to inundate low-lying Mid-Murrumbidgee River wetlands and support wetland vegetation; inundating sections of the Lowbidgee to support river red gum forest and woodland and lignum creeks and swamps; inundating areas of the Lowbidgee and providing habitat maintenance flows to Yanga National Park to support diversity and abundance of wetland fauna; and augmenting natural flows to enhance connectivity along and across components of the Murrumbidgee River.

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 New South Wales Office of Environment and Heritage, New South Wales Office of Water, NSW Department of Primary Industries, State Water Corporation, Coleambally Irrigation Corporation, Murrumbidgee Irrigation Limited 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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List of abbreviations

ABS	Australian Bureau of Statistics
AEW	Adaptive Environmental Water
AWD	Available Water Determination
CARM	Computer Aided River Management
CCD	Coleambally Catchment Drain
CEW	Commonwealth environmental water
CEWH	Commonwealth Environmental Water Holder
CICL	Coleambally Irrigation Cooperative Limited
CMA	Catchment Management Authority
COAG	Council of Australian Governments
CSIRO	Commonwealth Scientific and Industrial Research Organisation
DEC	Department of Environment and Climate Change (NSW)
DLWC	Department of Land and Water Conservation
DPI	NSW Department of Primary Industries
EEC	Endangered Ecological Community
EWA	Environmental Water Allocation
EWAG	Environmental Water Advisory Group
GDE	Groundwater Dependent Ecosystem
IMEF	Integrated Monitoring of Environmental Flows
IPA	Indigenous Protected Area
IPART	Independent Pricing and Regulatory Tribunal
IQQM	Integrated Quality Quantity Model
IUCN	International Union for Conservation of Nature
LGA	Local Government Area
HCVAE	High Conservation Value Aquatic Ecosystem
MDBA	Murray-Darling Basin Authority
MCMA	Murrumbidgee Catchment Management Authority
MEP	Monitoring Evaluation Plan
MER	Monitoring, evaluation and reporting
MEWAG	Murrumbidgee Environment Water Advisory Group
MIA	Murrumbidgee Irrigation Area
MI	Murrumbidgee Irrigation Limited
ML/d	Megalitres per day

ML/yr	Megalitres per year
NOW	NSW Office of Water
NSW	New South Wales
OEH	NSW Office of Environment and Heritage
RERP	Rivers Environmental Restoration Program
SA	Supplementary Access
SDL	Sustainable Diversion Limit
SEWPaC	Department of Sustainability, Environment, Water, Population and Communities
SKM	Sinclair Knight Merz Pty Ltd
SWC	State Water Corporation (NSW)
SWMOP	State Water Management Outcomes Plan (NSW)
WCC	Western Coleambally Channel
WSMP	Wanganella Swamp Management Plan
WSP	Water Sharing Plan
YACTAC	Yanco Creek and Tributaries Advisory Council

1. Overview

1.1 Scope and purpose of this document

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

To maximise the system's benefit achieved through the implementation of this document, three scales of watering objectives have been 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.

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

Assets and potential watering options have been identified for regions across the Murray-Darling basin (the basin). This work has been undertaken as 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 options have been developed for each asset to meet watering objectives under a range of volume scenarios. Efforts are also made to optimise the use of environmental water to maximise environmental outcomes at multiple assets, where possible.
3. Processes and mechanisms required to operationalise environmental water delivery have been documented and include:
   - delivery arrangements and operating procedures
   - water-delivery accounting methods (in consultation with operating authorities) 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 options for the delivery of environmental water within the Murrumbidgee Valley.

1.2 Relationship with other assets for the integrated use of environmental water

The Murrumbidgee River catchment adjoins the Lachlan River valley to the north and the Murray River valley to the south (Figure 1).

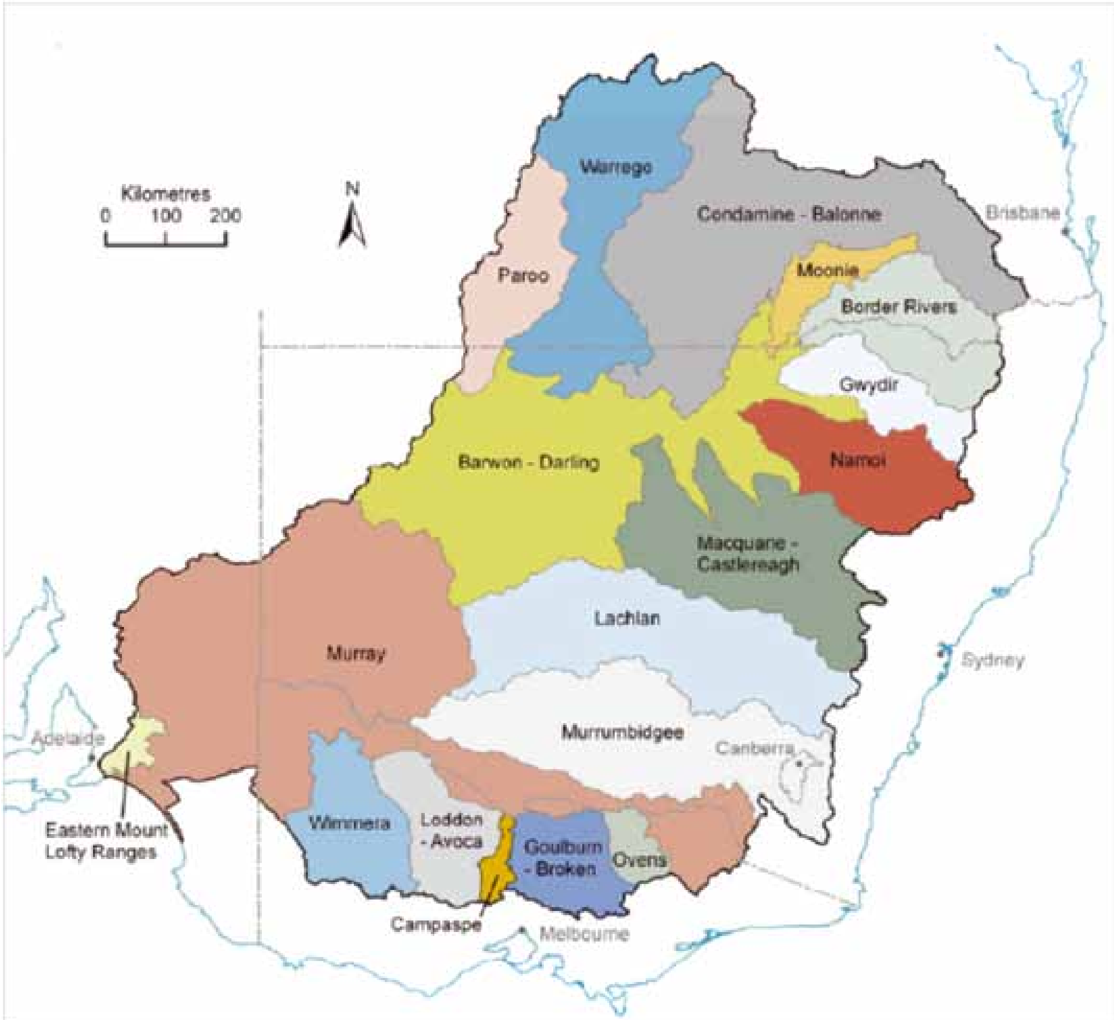


Figure 1: Location of the Murrumbidgee River catchment in the Murray-Darling basin. (Source: CSIRO 2008)

Flows in the Murrumbidgee River are currently managed to maintain minimum daily end-of-system flows at Balranald, and are calculated using the (modelled) 95th percentile natural daily flow for each month according to the *Water Sharing Plan for the Murrumbidgee Regulated River Water Source 2003* (NSW), (WSP 2003) (Table 1).

Table 1: Minimum daily flow requirements at Balranald (WSP 2003). (Source: Adam McLean, SWC, 2011).

Month	Minimum daily flow at Balranald (ML)
January	186
February	180
March	180
April	180
May	297
June	429
July	829
August	1,087
September	1,330
October	1,030
November	568
December	254

The Yanco Creek system discharges into the Edward River (a tributary of the Murray) via Billabong Creek. The gauge at Darlot measures end-of-system flows that discharge into the Edward-Wakool system. Water in the Murrumbidgee Irrigation Area (MIA) is supplied from the Murrumbidgee River and straddles Mirrool Creek, which is a tributary of the Lachlan River. However, Mirrool Creek rarely discharges into the Lachlan (only in large flood events) as terminal wetlands and distributary channels generally capture flows. Return flows from environmental watering in the Murrumbidgee River catchment may therefore also influence flows in the Murray, Lachlan and Edward Rivers.

1.3 Murrumbidgee River catchment and river system

The Murrumbidgee River catchment has an area of 87,348 square kilometres which is equivalent to about 11 per cent of the total land area of New South Wales (Murrumbidgee CMA 2006), and 8 per cent of the Murray-Darling basin (CSIRO 2008). The river originates in the alpine area of Kosciuszko National Park and flows through the Monaro High Plains and the low-lying plains of the western Riverina, joining the Murray River south of Balranald (Figure 2). In the upper reaches of the Murrumbidgee River, main tributaries include the Tumut, Queanbeyan, Yass and Cotter Rivers, and Tarcutta Creek downstream of the Tumut junction. Other key tributaries include Jugiong, Muttama, Adelong, Kyeamba, Adjungbilly, Gilmore and Billabong Creeks, and Goobarragandra River.

With a length of 1,600 kilometres, the Murrumbidgee River is the third longest of the rivers that traverse the basin. Average annual rainfall for the region is 530 millimetres and varies across the catchment, declining from east to west (1,500 millimetres in the east to 300 millimetres in the west) (CSIRO 2008). The western area of the catchment, which experiences a much drier climate than the eastern catchment, comprises a series of complex interconnected channels that traverse a vast inland delta. The deltaic system supports a number of vegetation communities characteristic of semi-arid conditions such as lignum shrublands and river red gum forests. Other vegetation types found in the Murrumbidgee catchment include alpine herb fields, native grasslands, wet forests and woodlands (CSIRO 2008). According to the CSIRO (2008), approximately 17 per cent of the catchment is covered with native vegetation. Although remaining vegetation communities are fragmented, conservation areas including Yanga National Park and Murrumbidgee Valley Nature Reserve have been established to protect important remnant vegetation such as the river red gum forests of the Lowbidgee Floodplain.

The Murrumbidgee catchment extends across 34 local government areas (Appendix A). The largest city in the catchment is Canberra (population of 314,000), followed by Wagga Wagga which is the largest inland city in New South Wales, with a population of 57,000 (ABS 2006). Other major urban centres and towns in the catchment include Griffith, Leeton, Hay, Yass, Gundagai, Narrandera and Jerilderie. These urban centres and surrounding rural areas rely on the water resources of the catchment to support rural industries like irrigated and dryland agriculture. Dryland pasture used for grazing, dryland cropping and irrigated agriculture are the main land uses. Land tenure in the Murrumbidgee catchment is primarily freehold, however there are also areas of nature conservation reserve including Yanga National Park and Murrumbidgee Valley Nature Reserve. Yanga National Park was gazetted in 2007 and covers an area of 31,190 hectares (Murrumbidgee CMA 2010).

The primary users of water in the region are the two major irrigation districts in the catchment—Murrumbidgee and Coleambally irrigation areas. Irrigation also occurs around Hay and Balranald and in eastern parts of the catchment, including around Wagga Wagga. The 2005–06 Agricultural Census identified cereal cropping as the largest area of irrigated agriculture (110,000 hectares) in the catchment, followed by rice (65,000 hectares). Burrinjuck and Blowering Dams provide regulated water. Burrinjuck Dam is situated in the upper catchment on the Murrumbidgee River and Blowering Dam is situated on the Tumut River. Collectively these storages have a capacity of 2,654,000 megalitres. Management of the water resource within the Murrumbidgee River catchment occurs according to the *Water Sharing Plan for the Murrumbidgee Regulated River Water Source 2003* (NSW). This water-sharing plan is currently being amended to include the Lowbidgee region.

Important hydrologic regions within the catchment are the:

- Mirrool Creek system
- Murrumbidgee River channel
- Mid-Murrumbidgee River Wetlands
- Lower Murrumbidgee Floodplain (or 'Lowbidgee Floodplain')
- Floodplain wetlands between Balranald and the Murrumbidgee River junction with the Murray River
- Yanco Creek system (including Billabong Creek).

Each is described further in Chapter 2.

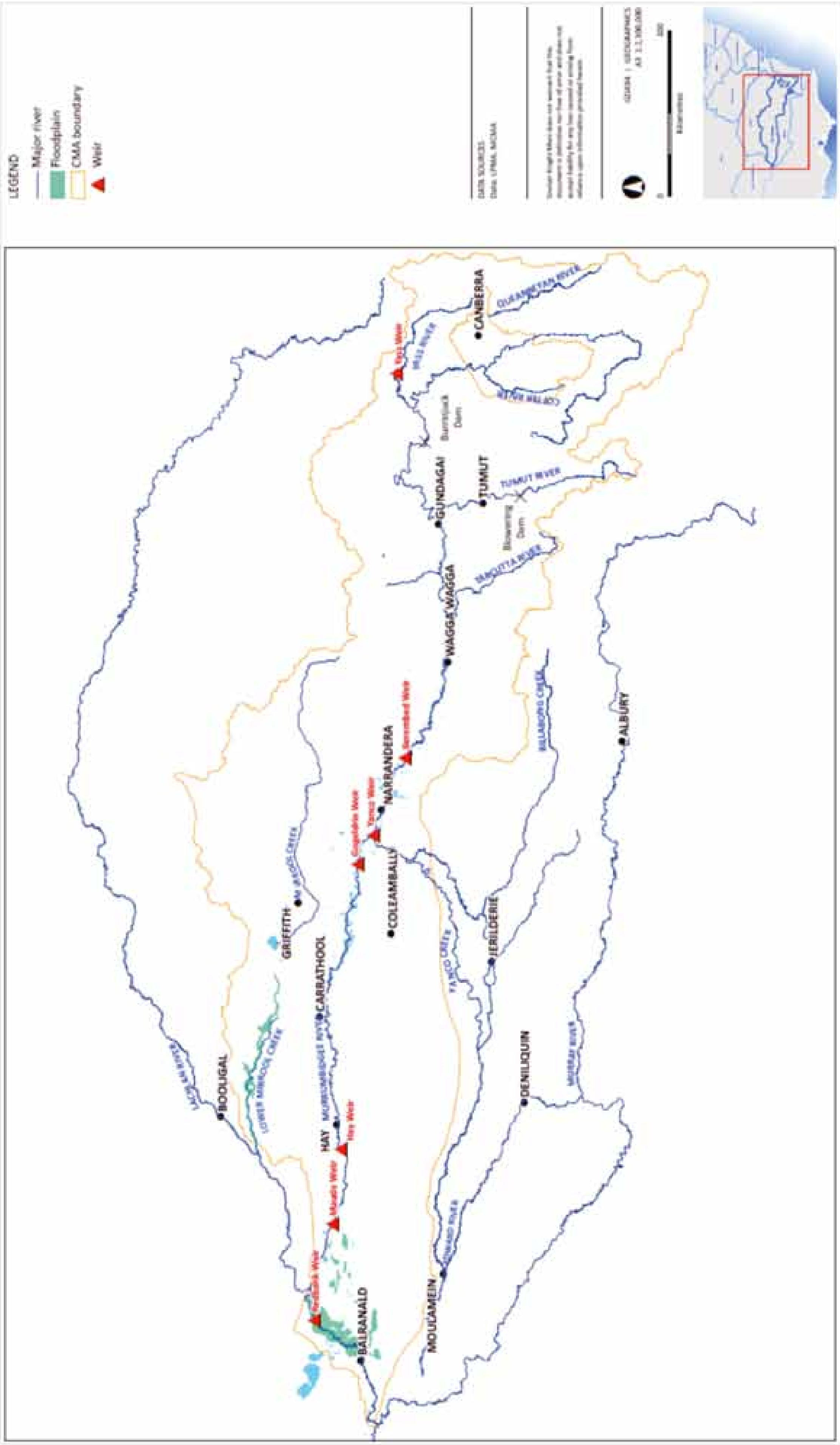


Figure 2: Murrumbidgee River catchment.

2. Ecological Assets and Their Values

Environmental assets as defined by the *Water Act 2007* (Commonwealth) include water-dependent ecosystem services, and sites with ecological significance. More specifically, these are defined as wetlands and river reaches, floodplains, groundwater dependent ecosystems (GDE), endangered ecological communities (EEC) and species reliant on freshwater systems, important drought refuge areas and ecosystem services.

Using this definition, ecological assets in the Murrumbidgee River catchment were identified via a search of relevant databases (e.g. Directory of Important Wetlands) and published and unpublished literature, and through consultation with relevant stakeholders in the catchment including agency and catchment management authority staff, and researchers. The resulting list includes freshwater-dependent biotic and abiotic assets such as areas of river red gum forest and woodland (*Eucalyptus camaldulensis*), black box woodland (*Eucalyptus largiflorens*), lignum (*Muehlenbeckia florulenta*), river-fed wetlands, wetlands listed under the Ramsar Convention treaty (the Convention on Wetlands of International Importance) and other migratory bird habitats, colonial bird breeding sites, and southern bell frog (*Litoria raniformis)* and fishing bat *(Myotis macropus)* habitat. Known significant habitats for these assets were then identified throughout the catchment for inclusion in the operational phase of the project. These are the:

- Mirrool Creek system and Murrumbidgee Irrigation Area (including Fivebough Swamp, Tuckerbil Swamp, Barren Box Swamp and the Lower Mirrool Creek Floodplain)
- Murrumbidgee River channel
- river-fed wetlands in the Murrumbidgee River system (from Gundagai to Maude, including the Mid-Murrumbidgee wetlands)
- Lowbidgee wetlands
- lowland floodplain wetlands in the Murrumbidgee River system (from Balranald to the Murray River junction, including 'the Junction' wetlands)
- river-fed wetlands in the Yanco Creek system (from the Murrumbidgee River to Moulamein).

Information regarding the location of biotic assets in relation to the key habitats identified above, current condition of these assets, their recent watering history, and watering requirements, was used to inform the creation of objectives to maintain or improve the condition of assets in the Murrumbidgee River catchment under four water availability scenarios.

Summary information about asset selection, condition, antecedent watering, and watering requirements is presented at Appendices B-E.

2.1 Ecological Values and Processes

2.1.1 Mirrool Creek system

Mirrool Creek is an ephemeral stream, and a tributary of the Lachlan River. The Creek originates near Temora and flows 250 kilometres west through the Murrumbidgee Irrigation Area (MIA), into the Lachlan River south of Booligal (Figure 3). The entire Mirrool Creek catchment occupies 11,000 square kilometres, with the upper reaches forming a wide floodplain with numerous small wetlands, and minimal channel definition (Whitten & Bennett 1999).

There are two distinct hydrological areas in the Mirrool Creek system. For the most part, the eastern portion of Mirrool Creek is integrated into the MIA supply and drainage system. This area has been largely cleared, intensively settled and modified by laser levelling. The natural hydrology, both surface and groundwater, has been considerably altered (Roberts 2005). The western portion of Mirrool Creek (downstream of Barren Box Swamp) has been altered to a lesser extent with larger areas of native vegetation remaining, mostly on soils that are not suitable for agriculture or in areas used for pastoral production (Eldridge 2002). To reflect this distinction and local terminology for these areas, the eastern portion of Mirrool Creek is hereafter referred to as the MIA, and the western portion hereafter referred to as the Lower Mirrool Creek Floodplain.

2.1.1.1 Murrumbidgee Irrigation Area (MIA)

Several significant wetlands occur in the MIA, which support habitat for vulnerable and threatened bird and amphibian species. Fivebough and Tuckerbil Swamps are listed under the Ramsar Convention.

Vegetation communities have changed significantly throughout the catchment as a result of grazing and irrigated farming in the MIA. For example, Fivebough and Tuckerbil Swamps were once black box-lignum depressions but irrigated farming resulted in the inundation of the black box woodland and subsequent dieback (Fivebough & Tuckerbil Swamp WMT 2002). Grazing pressure then altered the vegetation communities that favoured the inundated areas. Barren Box Swamp underwent a similar transition as a result of land use change and is currently undergoing revegetation as part of the Murrumbidgee Irrigation Limited (MI) Barren Box Storage and Rehabilitation Project.

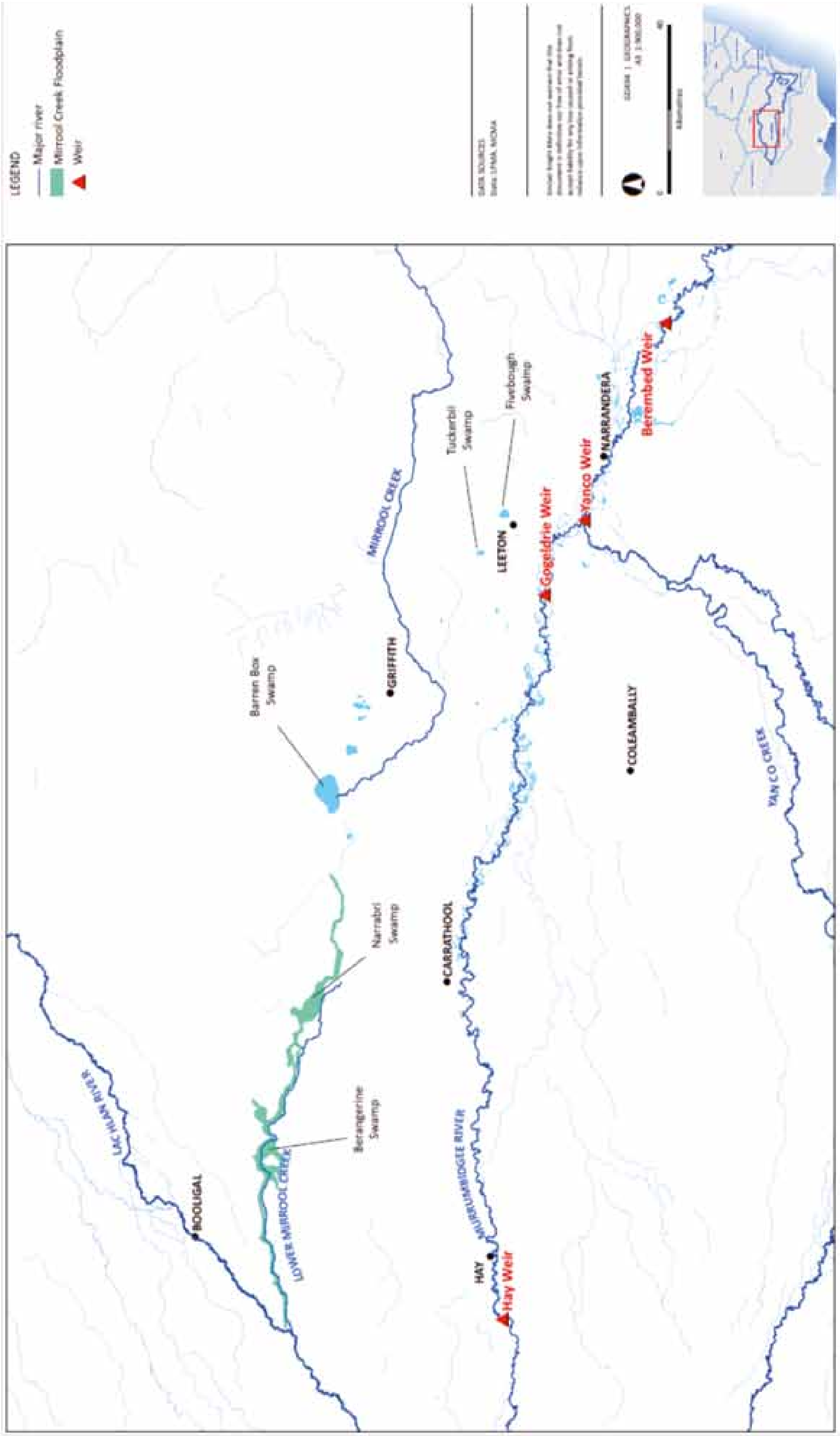


Figure 3: The Mirrool Creek system.

2.1.1.2 *Lower Mirrool Creek Floodplain*

The Lower Mirrool Creek Floodplain is listed as a nationally important wetland in the Directory of Important Wetlands. The floodplain is approximately 85 kilometres long, stretching to the Lachlan River, and ranges in width from eight metres to four kilometres. Six major wetlands occur on the floodplain: Narrabri, Five Oaks, Highway, Berangerine, Little Berangerine and Belaley Swamps.

2.1.2 Murrumbidgee River Channel

The character and context of the Murrumbidgee River changes from confined gorges and valleys in the cool uplands, through lower confined floodplains and riverine plains with large meander scars and anabranches in the temperate slopes, to open floodplains in the arid lands of the western plains (MDBC 2002). Downstream of Burrinjuck Dam the Murrumbidgee River can be divided into five zones based on geomorphic and hydrologic characteristics (MDBC 2002) (Table 2). Bank-full channel width varies from 80 metres at Wagga Wagga to less than 50 metres at Balranald, and stream energy is generally low (Page et al. 2005).

Table 2: Geomorphic reaches of the Murrumbidgee River below Burrinjuck Dam. (Source: Page & Nanson 1996 in MDBC 2002)

River Zone	Reach	Features
Burrinjuck Dam to Malebo Range	Confined Valley	Narrow floodplain confined by bordering hills (floodplain width 2–5 km)
Malebo Range to Narrandera	Wide Valley	Wider floodplain with little topographic confinement—some large meander scars and anabranches (floodplain width up to 10 km)
Narrandera to Carrathool	Riverine Plain Palaeo-floodplain	Substantial floodplain development with large meander cut-offs from Palaeo-floodplain (floodplain width 2–6 km)
Carrathool to Hay	Riverine Plain Confined floodplain	Narrow floodplain width and few wetlands (floodplain width <1.5 km)
Hay to Murray River	Lowbidgee	Very flat expansive floodplain with extensive marginal swamps (floodplain width reaches a maximum of 45 km before narrowing to less than 3 km below Balranald)

Native over-storey riparian vegetation includes river red gum, river cooba (*Acacia stenophylla*), black box and river oak (*Casuarina cunninghamiana*). However, plant communities are generally degraded with a high proportion of exotic species and poor regeneration of native species (Jansen & Robertson 2001 in MDBC 2002). The most common exotics include several species of willows (*Salix* spp.). The overall condition of the Murrumbidgee River downstream of Burrinjuck Dam is considered very poor (MDBC 2008), such that the Murrumbidgee River is included as part of the Natural Drainage System of the Lower Murray River Catchment aquatic endangered ecological community, listed under the *Fisheries Management Act 1994* (NSW). There are some isolated patches of plant communities that are in good condition and the lower Murrumbidgee River channel was recognised as a fish biodiversity hotspot with less degraded fish communities than more upstream parts of the river prior to the 2010–11 blackwater event (Gilligan 2005).

2.1.3 Mid-Murrumbidgee Wetlands

The Mid-Murrumbidgee Wetlands system is located on the Murrumbidgee River floodplain between Wagga Wagga and Carrathool (MDBA 2010). The wide floodplain and remnants of a paleo river system contribute to the formation of approximately 5,000 wetlands of varying sizes and distances from the current Murrumbidgee River channel (MDBA 2010). Several of these are listed as nationally important in the Directory of Important Wetlands in Australia (DEWHA 1998). They support open water habitat and include aquatic macrophytes such as spike rushes (*Juncus* spp. or *Eleocharis* spp.), garland lily (*Calostemma purpureum*) and blanket fern (*Pleurosorus rutiflolius*) (CSIRO 2008). Riparian over-storey vegetation is dominated by river red gum forest and woodland, with black box woodland on the floodplain (NRC 2009). Several of the wetlands rarely dry out, providing important drought refuge for a range of flora and fauna, including threatened species (MDBA 2010).

The Mid-Murrumbidgee Wetlands are also part of the Natural Drainage System of the Lower Murray River Catchment aquatic endangered ecological community, listed under the *Fisheries Management Act 1994* (NSW).

2.1.4 The Lower Murrumbidgee Floodplain (Lowbidgee Floodplain)

The Lowbidgee Floodplain is listed on the Directory of Important Wetlands in Australia (Environment Australia 2001). This nationally significant area comprises a complex of three wetland systems with distinct hydrological characteristics and ecological features on the floodplain between Hay and Balranald (Figure 4). These are the Nimmie-Caira, Fiddlers-Uara Creek and Redbank systems. Watering of these wetlands is highly dependent upon flows from the Murrumbidgee River (Kingsford & Thomas 2004).

The Lowbidgee Floodplain wetland ecosystem is recognised as an area of high conservation value as it provides important habitat for a range of aquatic and terrestrial species including frogs, fish and waterbirds. The floodplain also supports significant areas of river red gum forests, while wetlands in the area provide habitat for Australian Government and state-listed threatened species, the southern bell frog and fishing bat (state-listed only), and support some of the largest recorded breeding colonies of waterbirds in NSW.

Vegetation communities of the Lowbidgee Floodplain vary considerably across the different hydrological strata and depend on specific watering regimes and soil conditions. Areas subject to more frequent flooding such as the Nimmie-Caira system support extensive areas of lignum, while areas subject to less frequent flooding (isolated or stranded by infrastructure), such as the Fiddlers-Uara system support lignum and black box woodland. Wetlands of the Lowbidgee Floodplain form part of the *Fisheries Management Act 1994* (NSW) Aquatic Ecological Community in the Natural Drainage System of the Lower Murray River Catchment endangered ecological community. In the Redbank system, some river red gum forests remained dry for up to 10 years until flooding in 2010, while others have been more regularly inundated. In general, regulation has reduced the frequency of natural flood events that inundate the Lowbidgee wetland system. Combined with the effects of agriculture, this has reduced the extent of the wetlands.

Reduced and fragmented wetland habitat combined with drought conditions has placed pressure on a number of waterbird species and also the southern bell frog. Wassens et al. (2008) found that wetlands that were flooding annually were more likely to support the southern bell frog than those less frequently flooded. A number of wetlands in the Redbank and Nimmie-Caira systems provide core habitat for the southern bell frog.

Agriculture on the Lowbidgee Floodplain includes a mixture of grazing, cropping and forestry. Grazing was historically the dominant land use in the Nimmie-Caira system, but a shift in commodity prices meant that landholders in the Nimmie-Caira turned to cropping (Murrumbidgee CMA 2010). However, drought conditions over eight consecutive years resulted in a reduction in cropping (Murrumbidgee CMA 2010). Decreased flooding in the Fiddlers-Uara system has reduced the capacity to grow crops and support large stock numbers. Land use in Redbank North includes agroforestry, conventional irrigation, dryland cropping and grazing, while much of Yanga is national park (Murrumbidgee CMA 2010).

2.1.5 Floodplain Wetlands—Balranald to Murray River Junction

The Balranald to Murray River junction reach of the Murrumbidgee River extends 21 kilometres south west of Balranald until its confluence with the Murray River (Figure 5). At Balranald, the floodplain consists of a narrow band of land either side of the Murrumbidgee River but it expands into a broad delta west of Waldaira Lake, incorporating a number of creeks and lagoons (e.g. Jack O'Brien's, Mainie and Peacock Creeks), and areas of river red gum woodland, black box and mallee.

The area is environmentally significant with a number of threatened species reliant on the riparian and woodland habitats, in addition to ibis (*Threskiornis* spp. and *Plegadis falcinellus*), cormorant (*Phalacrocorax* spp.) and spoonbill (*Platalea* spp.) rookeries at wetlands on the floodplain. Specific assets include Waldaira Lake, Bulumpla Lagoon, Chalmers Lagoon, Pelican Lagoon, Mainie Station Lagoon, Peacock Creek Flora Reserve and the Murrumbidgee River channel and corridor.

The area downstream of Balranald is mainly used for grazing, with small areas of irrigation and lake-bed cropping.

The reach lies across three catchment management areas (Murrumbidgee, Murray and Lower Murray Darling CMAs).

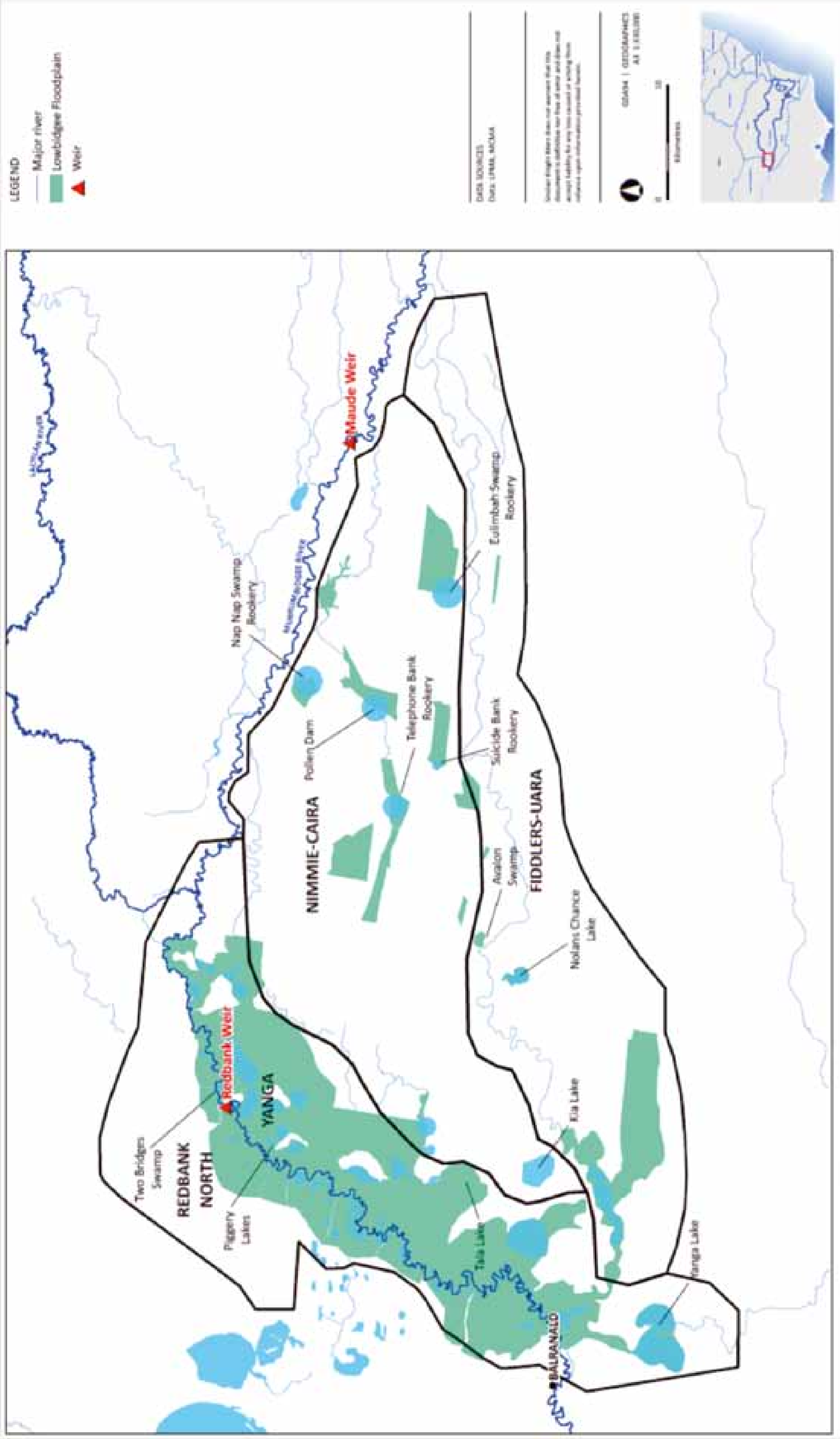


Figure 4: The Lowbidgee Floodplain.

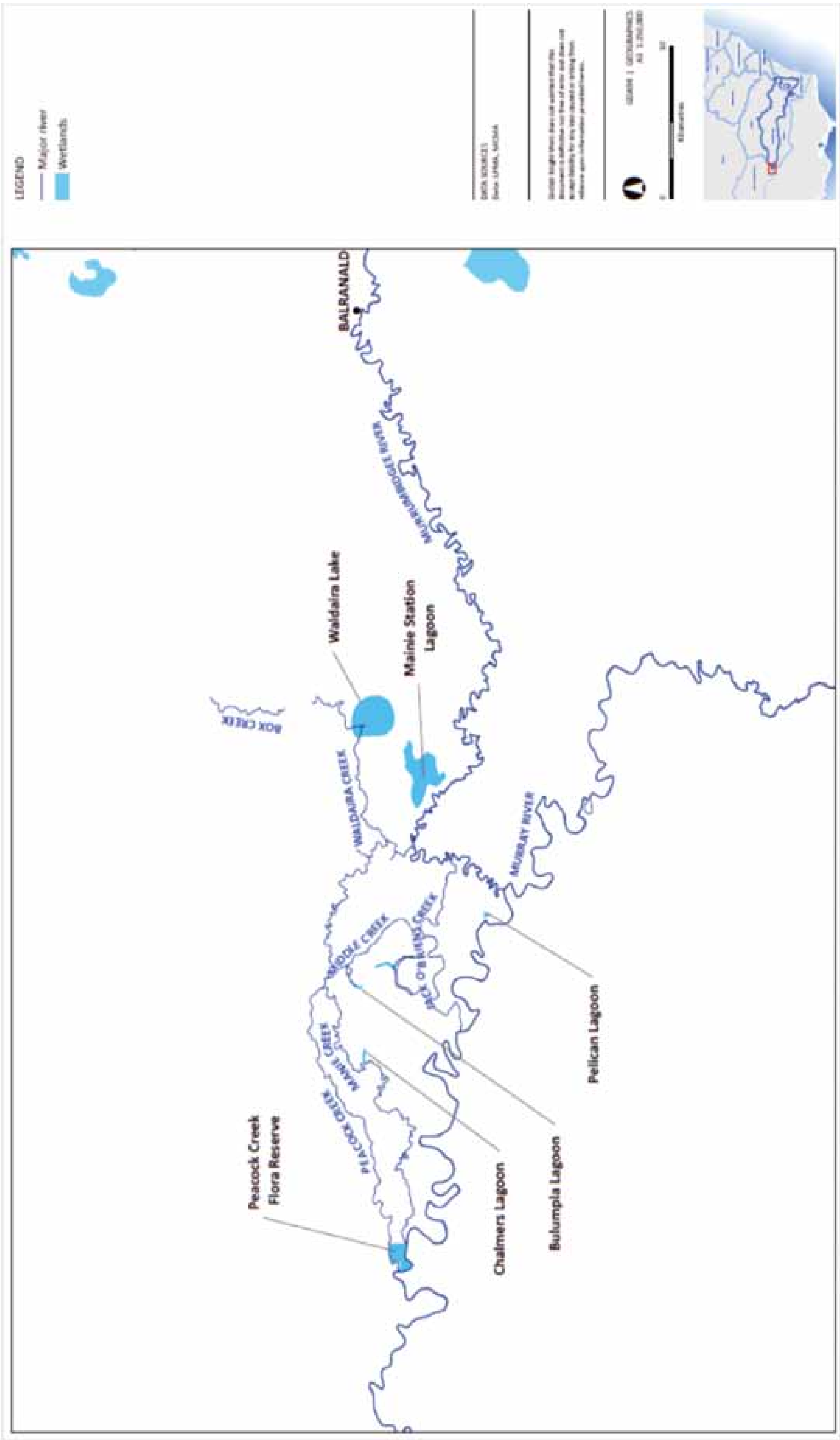


Figure 5: Floodplain wetlands—Balranald to the Murray River junction.

2.1.6 Yanco Creek System

Yanco Creek is both a major effluent stream of the Murrumbidgee River and a tributary system of the Murray River (Glazebrook 2000). Yanco Creek bifurcates from the Murrumbidgee approximately 15 kilometres west of Narrandera (Figure 6).

Just north of Morundah, Yanco Creek bifurcates to form Colombo Creek. The two creeks flow parallel to each other through the Murrumbidgee riverine plains in a south-westerly direction, forming a wide floodplain (Figure 6). Upstream of Jerilderie, Cocketgedong Creek drains from Lake Urana and joins Colombo Creek upstream of Billabong Creek. Approximately 55 kilometres downstream, Yanco and Billabong Creeks join (near Conargo). Flows from Billabong Creek meet the Edward River at Moulamein, which then flows into the Wakool River. The Wakool River joins the Murray River downstream of Stoney Crossing. The Forest Creek system is an anabranch of Billabong Creek and consists of a number of creeks including Forest Creek, Eight Mile Creek, Box Creek, Estuary Creek and the Forest Anabranch.

Key wetland areas are Molly's Lagoon/Dry Lake Complex, a series of floodplain wetland complexes on upper Yanco Creek, including Gum Hole/Possum Creek Complex, Arrawidgee Complex, Silver Pines Complex, Bundure Complex, The Frontage Complex, Lake Urana, Mundoora/Wilson Creek Anabranch, Wanganella Swamp, Kerribirri Swamp, 'Rhyola' depressions and flood runners, break out areas on 'Back Nullum', and Box Swamp on 'Blue Gate'.

Wanganella Swamp is approximately 470 hectares of reed wetland, located in the Forest Creek system. It is particularly significant for its waterbird breeding habitat, providing opportunities for threatened species such as the Australasian bittern (*Botaurus poiciloptilus*) (Webster & Davidson 2010).

Irrigation channels and dams near Colleambally provide critical habitat for the southern bell frog (Beal et al. 2004). Numerous other threatened species reliant on floodplain and riverine habitats also occur in the Yanco Creek system (Appendix B).

Wanganella Swamp and assets downstream are not in the Murrumbidgee Catchment Management Area, however they are included in this report because they are reliant on flows from the Murrumbidgee River.

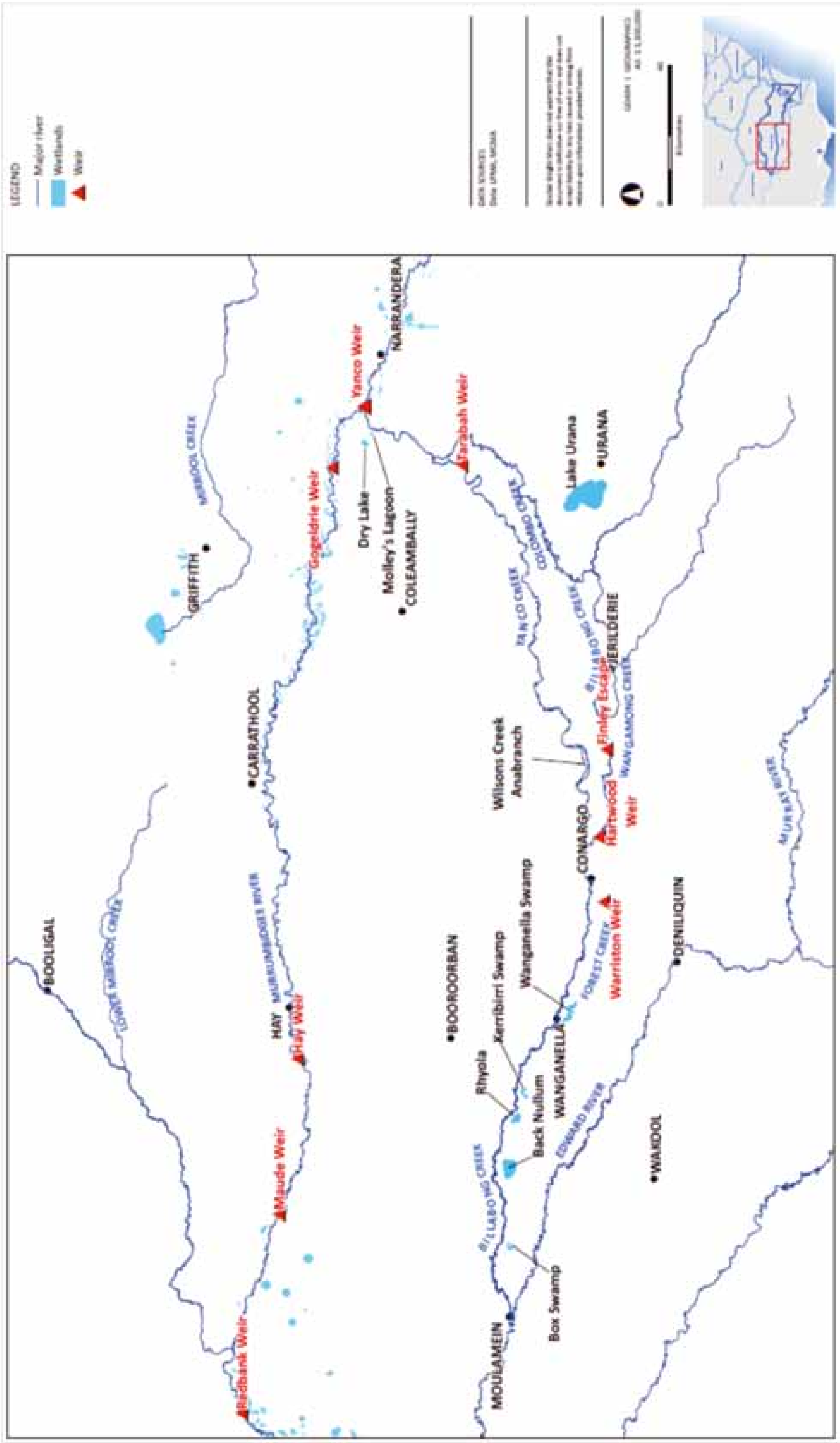


Figure 6: The Yanco Creek system.

3. Watering Objectives

Watering options presented in this chapter are based on current understanding of the type, character, location and condition of ecological assets and their watering requirements in the Murrumbidgee River catchment. The following sections provide broad-scale and asset-scale objectives for maintaining or improving asset condition and watering options under a range of water availability scenarios.

3.1 Broad-scale functional objectives

The *Water Sharing Plan for the Murrumbidgee River Regulated Water Source 2003* (NSW) cites the following applicable broad-scale objectives for the Murrumbidgee River:

1) protect and restore in-river and riparian habitats and ecological processes
2) provide for appropriate watering regimes for wetlands
3) sustain and enhance population numbers and diversity of indigenous species
4) protect end-of-system flows
5) promote the recovery of known threatened species.

These objectives set the basis for environmental water allocation and use in the Murrumbidgee River system. The following asset-scale objectives were created in accordance with these broad-scale functional objectives.

3.2 Asset-scale ecological and hydrological objectives

The asset-scale objectives focus on maintaining and improving wetland and floodplain vegetation communities, and providing habitat conditions supportive of threatened and significant other species (such as migratory waterbirds), and endangered ecological communities (Table 3). These align with environmental objectives of the Murray-Darling Basin Authority (MDBA), as well as with Murrumbidgee Catchment Management Authority (2008) *Catchment Action Plan* goals to maintain the extent, and improve the character, of floodplain wetlands in the catchment.

The overall goals are to:

- restore the extent and condition of riverine, riparian wetland and floodplain vegetation communities
- maintain known colonial waterbird breeding sites in 'event ready' condition
- maintain seasonal habitats for migratory waterbirds
- maintain known southern bell frog breeding sites in 'event ready' condition
- restore longitudinal and lateral connectivity between as many of the components of the Murrumbidgee River as possible to protect and restore the "aquatic ecological community in the natural drainage system of the Lower Murray River catchment", including its threatened species.

The rationale for inclusion of each objective is discussed in Table 3. The objectives for various vegetation communities are included on the premise that they contribute significantly to the ecological character of the Murrumbidgee River catchment, and that their condition is intrinsically linked with many other assets by providing habitat and acting as surrogate indicators. Hence the justification for these includes the role of the vegetation community in overall ecosystem structure and function, often in relation to the provision of habitat for fauna. Table 3 also includes hydrological objectives for corresponding key habitats. These were created using Roberts and Marston (2000), Childs et al. (2010), Spencer and Wassens (2010), and Scott (1997).

Although there are numerous threatened species in the Murrumbidgee River catchment, southern bell frogs are included as a target species for watering for a number of reasons. For example, the composition of frog communities and the breeding patterns of residents are closely linked to wetland hydrology and vegetation (Jansen & Healey 2003), so they are a good indicator of wetland and riverine health. Southern bell frogs also have specific water requirements, exhibit strong seasonal patterns in activity and are able to move large distances between suitable wetlands. The species forages in terrestrial areas, and breeds in wetlands so its presence is linked to both wetland and terrestrial conditions across the floodplain. The southern bell frog is listed as a vulnerable species under the *Environment Protection and Biodiversity Conservation Act 1999* (Commonwealth) and has undergone significant range declines over the past 30 years. Conservation of core habitats and maintenance of the remnant population in the Murrumbidgee River catchment is therefore a priority.

Table 3: Proposed broad-scale medium to long-term ecological and hydrological objectives to maintain and improve riverine and floodplain condition in the Murrumbidgee River catchment.

Ecological Objective	Justification	Hydrological Objective
1. Ecological Function Objective		
1.1 Restore longitudinal and lateral connectivity between as many of the components of the Murrumbidgee River as possible to protect and restore the endangered ecological community, including its threatened species.	The Murrumbidgee River is part of the catchment of the lower Murray River drainage system, which is listed as an endangered ecological community under the *Fisheries Management Act* (NSW). Water transports sediments, nutrients and energy, determines or influences the morphology of river channels and wetlands, and is an important vector for movement of aquatic biota, all of which contribute to the health and resilience of an ecosystem.	• Full range of flows as specified for 2.1–3.3.
2. Wetland vegetation community (habitat surrogates) objectives.		
Goal: To restore the extent and condition of riverine, riparian wetland and floodplain vegetation communities.		
2.1 Maintain and restore wetland vegetation communities to good condition.	Semi-permanent vegetation communities (water lilies, water ribbons, spike rushes and reeds) provide feeding, breeding and refuge habitats for a diversity of important wetland, floodplain and terrestrial biota. They contribute substantially to the ecological character and function of the Murrumbidgee River and associated floodplain.	• Requires annual sustained flooding 0.20–1 m, duration >16 weeks (Roberts & Marston 2000). • Optimum timing is late winter/spring. • Some species (e.g. spike rushes) are sensitive to rates of recession. Roberts and Marston (2000) recommend 2 cm/day.
2.2 Maintain and restore river red gum forest and woodland communities to good condition.	The Murrumbidgee (especially the Lowbidgee) supports large stands of river red gums, with both forest and woodland occurring according to watering regimes. These have a range of understorey structures and species, and contribute substantially to ecosystem structure and function in the catchment.	• River red gum forest requires an average flood frequency of 1 in 3 years, duration 4–7 months in winter/spring, and not lasting more than 24 months continuous flooding or without flooding. • River red gum woodland requires an average flood frequency of 1 in 5 years, duration 4–7 months in winter/spring and not lasting more than 24 months continuous flooding.
2.3 Maintain and restore black box woodlands to good condition.	Black box communities contribute to the ecological character of the Murrumbidgee floodplain. When these areas are inundated most other habitats in the Murrumbidgee are also wet, creating recruitment and dispersal opportunities for many species. Black box woodlands also provide important habitat for a range of fauna and flora.	• Black box woodland requires flooding every 3–5 years, duration 2–4 months to 0.3 m in winter/spring. It must not be flooded longer than 12 months.
2.4 Maintain and restore Lignum shrublands to good condition.	Lignum provides a preferred nesting substrate either as an understorey shrub to other woody species or as a shrubland for ibis and spoonbills.	• Requires flooding every 2–8 years, for 3–12 months duration. Complete drying between floods is required to ensure soil cracking for soil aeration and deep soil water recharge upon re-flooding.

Ecological Objective	Justification	Hydrological Objective
2.5 Maintain open water areas and exposed muddy margins.	Numerous small lagoons and other wetlands are scattered throughout the Murrumbidgee floodplain, adding habitat diversity for shorebirds during drying phases and providing opportunities for important behavioural cues for waterfowl and waders.	• Requires maintenance and top-up flows in conjunction with Objective 2.1. Drawdowns should coincide with late summer-autumn timing for waterbirds.
3. Other Ecological Asset Objectives		
Goal: To support diversity and abundance of wetland fauna populations.		
3.1 Maintain known colonial waterbird breeding sites in 'event ready' condition, and support breeding events.	The Murrumbidgee River catchment includes Ramsar-listed wetlands, and other important sites recognised as key breeding habitat for colonial waterbirds (ibis, egret, cormorant and herons). Key sites occur in river red gum, lignum, black box and common reed communities in the Lowbidgee, Yanco Creek and Mid-Murrumbidgee Wetlands.	• In addition to habitat maintenance flows identified above, additional flows may be required to ensure successful completion of colonial nesting events by extending flow duration (need to maintain inundation levels at breeding and feeding sites for average of 10 months).
3.2 Maintain seasonal habitats for migratory waterbirds.	Several waterbird species occurring regularly in the Murrumbidgee catchment are listed as being of significance under international agreements (JAMBA, CAMBA, ROKAMBA).	• As for 2.1 and 2.5.
3.3 Maintain known southern bell frog breeding sites in 'event ready' condition, and support breeding events.	The Murrumbidgee River catchment provides important habitat for Commonwealth and state-listed threatened southern bell frog. Wetlands in the Lowbidgee in particular provide essential breeding habitat for the species. Southern bell frogs have also been found in two Mid-Murrumbidgee Wetlands (Sunshower and Gooragool Lagoons).	• As for 2.1, 2.2 and 2.4.
3.4 Maintain or improve ecosystem condition in the Murrumbidgee River channel.	The Murrumbidgee River is part of the catchment of the lower Murray River drainage system, which is listed as an endangered ecological community under the *Fisheries Management Act*. Water transports sediments, nutrients and energy, determines or influences the morphology of river channels and wetlands, and is an important vector for movement of aquatic biota, all of which contribute to fertility and resilience of an ecosystem. The channel provides core habitat for aquatic flora and fauna species, and refuge habitat for a suite of terrestrial species. Fish species in particular are affected by water quality, and longitudinal and lateral connectivity.	• Full range of flows as specified for 2.1–3.3. • Requires sufficient baseflow and freshes to maintain suitable water quality in refuge pools and channel in the regulated river during drought years. • Requires sufficient baseflows and freshes to avoid build-up of organic matter and maintain riparian and in-stream vegetation health. • Requires sufficient flows to maintain natural rates of rise and fall and allow the completion of aquatic organism lifecycles.

3.3 Watering options

Watering options for environmental assets presented in Table 4 aim to meet the ecological objectives expressed in Table 3 for environmental assets under a range of water availability scenarios (i.e. extreme dry, dry, median and wet). They align with the watering and management objectives of Commonwealth environmental water (DEWHA 2010) as well as with the NSW Office of Environment and Heritage (OEH) objectives for water use.

In general, the watering options were developed using the following ecological benchmarks for water availability conditions:

- Extreme dry—avoid damage to key environmental assets.
- Dry—ensure ecological capacity for recovery.
- Median—maintain ecological health and resilience.
- Wet—improve and extend healthy and resilient aquatic ecosystems.

In practice this translates into using an 'ecology triage' approach in extremely dry conditions, whereby supporting the critical needs of refugia and threatened species are paramount. As water availability increases, the focus is on inundating progressively more area of floodplain for longer, providing optimal seasonal flow patterns and supporting/optimising biological responses to inundation such as reproduction, recruitment, dispersal and growth. Thus, while there are fewer watering opportunities during extreme dry and dry conditions, actions taken during median and wet periods predispose these habitats and species to greater resilience during dry periods.

Given this approach, the annual watering objectives for the extreme dry scenario listed in Table 4 focus on providing refuge habitat for southern bell frogs in the Lowbidgee to maintain core breeding populations of the species, whilst supporting other key flora and fauna. The dry scenario includes watering of Mid-Murrumbidgee wetlands to provide a mosaic of wetting and drying habitats for flora and fauna throughout the catchment, plus maintenance watering at southern bell frog habitats and colonial waterbird nesting sites. The median scenario allows for watering more wetland and floodplain habitats for longer periods of time, including Fivebough and Tuckerbil Swamps in the MIA system; taking advantage of higher water conditions in the Murray River to inundate floodplain river red gum wetlands south of Balranald; watering a suite of habitats in Yanga National Park and other areas of the Lowbidgee; piggybacking to prolong high and flood flows throughout the Murrumbidgee River catchment to enhance watering of the Mid-Murrumbidgee wetlands; and providing flows to environmental assets in the Yanco Creek system. The wettest scenario provides sufficient water to inundate assets on the floodplain and it can also increase the area and duration of inundation to extend and improve floodplain and wetland communities. Further details on the specific volume requirements of assets and the delivery of water to these are provided in Chapter 4.

Please note that further information relating to the specific watering requirements of related assets in the Murrumbidgee catchment is presented in appendices to this document, with the specific watering requirements to support the maintenance and recruitment of biotic components are presented in Appendix E.

3.3.1 Murrumbidgee River channel objectives

Although the Murrumbidgee River channel is recognised as an asset in the catchment, it is assumed the broad-scale medium to long-term ecological and hydrological objective offered in Table 3 (Objective 3.4) is met in providing environmental flows for the remaining assets in the catchment, especially the bank-full and overbank flows required to inundate the Mid-Murrumbidgee Wetlands, and in piggybacked flows. Translucency flows in the upper catchment will also contribute to meeting within-channel ecological requirements upstream of Tumut. However, it is unlikely all within-channel ecological requirements can be met by environmental flows intended to support floodplain wetlands and downstream assets. Although the effects of river regulation on the seasonality and variability of natural flows in the Murrumbidgee River are well documented (see Whitten & Bennett 1999, MDBC 2002, CSIRO 2008), and while there is information available on the ecological outcomes of promoting connectivity between rivers and floodplains (e.g. Hardwick et al. 2001, Thoms 2002, Lyon et al. 2010), there is little published information on the relative benefits of environmental flows for within-channel assets in Australian dryland river systems (Bowmer 2003). One study conducted in the Murrumbidgee River (Ryder et al. 2007) established that depending on the timing and magnitude of environmental flows, they could be used to either enhance in-stream productivity by scouring nutrients and salts from in-channel habitats, or reduce nutrient availability for downstream food webs by diluting nutrient rich floodwaters from catchmentzscale run-off events.

3.3.2 Antecedent watering conditions

The watering options for environmental assets presented in Table 4 make no reference to antecedent conditions at the asset, in the catchment, or at the two major storages. That is, they were created specifically to meet the management objectives for the four discrete annual water availability scenarios irrespective of past or predicted future water availability and climatic conditions. However, it is acknowledged that information relating to asset antecedent conditions in particular, contributes to prioritising where and when to deliver environmental flows for maximum ecological benefit at an asset, and integrated across many assets throughout the catchment. Information relating to asset condition and the last time assets were watered (as at January 2011) is presented at Appendix D, while asset watering requirements for maintenance of populations and recruitment, and critical thresholds for watering beyond which asset condition would be expected to decline, are presented at Appendix E.

Table 4: Proposed broad-scale functional and ecological objectives under different water availability scenarios for annual watering to maintain and improve riverine and floodplain communities of the Murrumbidgee River catchment (based on available Commonwealth environmental water at 4 October 2011).

Environmental Asset	Management objectives for specific water availability scenarios			
	Extreme Dry	Dry	Median	Wet
	Goal: Avoid damage to key environmental assets	Goal: Ensure ecological capacity for recovery	Goal: Maintain ecological health and resilience	Goal: Improve and extend healthy and resilient aquatic ecosystems
Water Availability	Minimum allocation on record	30^{th} Percentile Year	50^{th} Percentile Year	70^{th} Percentile Year
CEW Allocation Volume				
High Security	429 ML*0.95	429 ML	429 ML	429 ML
General Security	Nil	118,568 ML*0.44 (October) 118,568 ML*0.60 (June)	118,568 ML*0.58 (October) 118,568 ML*0.84 (June)	118,568 ML*0.74 (October) 118,568 ML*1.0 (June)
Supplementary	20 820 ML#	20,820 ML#	20,820 ML#	20,820 ML#
Other Allocated/Available Environmental Water				
EWA	Nil	13,000 (October) 0 (June)	50,000 (October) 49,000 (June)	80,000 (October) 90,000 (June)
Adaptive environmental water (OEH GS)	Assumed Nil	6,634 ML*0.44 (October) 6,634 ML*0.60 (June)	6,634 ML*0.58 (October) 6,634 ML*0.84 (June)	6,634 ML*0.74 (October) 6,634 ML*1.0 9June)
Adaptive environmental water (OEH Supplementary)	Assumed Nil	Maximum 5,679 ML	Maximum 5,679 ML	Maximum 5,679 ML

Environmental Asset	Management objectives for specific water availability scenarios			
	Extreme Dry	Dry	Median	Wet
	Goal: Avoid damage to key environmental assets	Goal: Ensure ecological capacity for recovery	Goal: Maintain ecological health and resilience	Goal: Improve and extend healthy and resilient aquatic ecosystems
1. River-fed wetlands (Gundagai to Maude (includes all the Mid-Murrumbidgee wetlands).	• No options—requires median levels of water availability.	• Should a suitable piggyback event occur, seek to provide 27,000 ML/d at Wagga Wagga to inundate low-lying Mid-Murrumbidgee Wetlands, or use irrigation infrastructure to inundate prioritised Mid-Murrumbidgee River wetlands (e.g. McKenna's Lagoon, various MIA National Park wetlands, Sunshower Lagoon). Inundate these for at least three months to create a mosaic of wetting and drying habitats throughout the catchment, and maintain wetland vegetation communities to good condition.	• Should a suitable rainfall event occur (with a peak over 45,000 ML/d at Wagga Wagga) seek to provide for a more natural recession in flows once flows are less than 30,000 ML/d at Gundagai (noting that the current SWC Water Supply Work Approval limits regulated releases to 32,000 ML/d at Gundagai and 9,300 ML/d at Tumut River), or use irrigation infrastructure to inundate prioritised Mid-Murrumbidgee River wetlands (e.g. McKenna's Lagoon, various MIA National Park wetlands, Sunshower Lagoon). Inundate these for at least three months to create a mosaic of wetting and drying habitats throughout the catchment, and maintain and/or wetland vegetation communities to good condition. • Increase the area and duration of inundation of high conservation value Mid-Murrumbidgee Wetlands to maintain or improve wetland vegetation communities to good condition. • Inundate these for at least five months, commencing in spring. Use carryover to provide optimal seasonal flow patterns in subsequent years. • Piggyback releases onto significant tributary freshes inundating the low-lying river-fed wetlands from Gundagai to Maude Weir, increasing high flow duration and extent across the floodplain.	• Should a suitable rainfall event occur (with a peak over 60,000 ML/d at Wagga Wagga) seek to provide for a more natural recession in flows once flows are less than 30,000 ML/d at Gundagai (noting that the current Water Supply Work Approval limits regulated releases to 32,000 ML/d at Gundagai and 9,300 ML/d at Tumut River), or use irrigation infrastructure to inundate prioritised Mid-Murrumbidgee River wetlands (e.g. McKenna's Lagoon, various MIA National Park wetlands, Sunshower Lagoon). Inundate these for at least three months to create a mosaic of wetting and drying habitats throughout the catchment, and maintain and/or wetland vegetation communities to good condition. • Increase the area and duration (>7 months) of inundation of Mid-Murrumbidgee Wetlands, to maintain and/or improve wetland vegetation communities to good condition. • Piggyback releases onto significant tributary freshes inundating the majority of river-fed wetlands from Gundagai to Maude Weir, and increasing high flow duration and extent across the floodplain. • Maintain and complete any colonial waterbird breeding event initiated by natural flood event or environmental flows.
2. Fivebough Swamp	• Use available water to inundate Fivebough Swamp. Water traded in from the Murray River, or carryover, could be used. Requires approximately 500 ML.	• Use available water to inundate Fivebough Swamp. Water traded in from the Murray River, or carryover, could be used. Requires approximately 500 ML.	• Inundate Fivebough Swamp to maintain or improve wetland vegetation communities to good condition. Requires approximately 500 ML.	• Inundate Fivebough Swamp to maintain or improve wetland vegetation communities to good condition. Requires approximately 500 ML.

Environmental Asset	Management objectives for specific water availability scenarios			
	Extreme Dry	Dry	Median	Wet
	Goal: Avoid damage to key environmental assets	Goal: Ensure ecological capacity for recovery	Goal: Maintain ecological health and resilience	Goal: Improve and extend healthy and resilient aquatic ecosystems
3. Tuckerbil Swamp	• Use available water to inundate Tuckerbil Swamp. Water traded in from the Murray River, or carryover, could be used. Requires approximately 500 ML.	• Use available water to inundate Tuckerbil Swamp. Water traded in from the Murray River, or carryover, could be used. Requires approximately 500 ML.	• Inundate Tuckerbil Swamp to maintain or improve wetland vegetation communities to good condition. Requires approximately 500 ML.	• Inundate Tuckerbil Swamp maintain or improve wetland vegetation communities to good condition. Requires approximately 500 ML.
4. Barren Box Swamp	• No options—requires median levels of water availability.	• No options—requires median levels of water availability.	• Inundate the wetland area of the Wetland Cell. This requires 3,000–5,000 ML.	• Increase the area and duration of inundation in the Wetland Cell, in accordance with the MI (2008) Barren Box Wetland Rehabilitation Plan. • Maintain and complete waterbird breeding events initiated by environmental flows.
5. Lower Mirrool Creek Floodplain	• No options—requires wet levels of water availability.	• No options—requires wet levels of water availability.	• No options—requires wet levels of water availability.	• Inundate the system flooding river-fed wetlands throughout the system, to maintain and/or improve black box woodland to good condition.
6. Lowland river-fed wetlands (Balranald to Murray River junction, including 'the Junction' wetlands)	• No options—requires median levels of water availability.	• No options—requires median levels of water availability.	• Ensure 'the Junction wetlands' are watered by managing high Murrumbidgee flows to coincide with high Murray River flows. • Piggyback releases onto significant Murrumbidgee and Murray River flows to inundate the Junction wetlands south of Balranald. • Requires delivery of >5,000 ML/d downstream of Balranald Redbank Weir in addition to Murray River flow >10,000 ML/d at Braham on the Murray River for a period of several weeks.	• Increase the area of river red gum woodland communities in good condition by watering more wetlands for longer (e.g. at least five months). • Requires delivery of >5,000 ML/d downstream of Balranald Weir in addition to Murray River flow >10,000 ML/dML/d at Barham on the Murray River for a period of several weeks.

Environmental Asset	Management objectives for specific water availability scenarios			
	Extreme Dry	Dry	Median	Wet
	Goal: Avoid damage to key environmental assets	Goal: Ensure ecological capacity for recovery	Goal: Maintain ecological health and resilience	Goal: Improve and extend healthy and resilient aquatic ecosystems
7. Lowbidgee Wetlands	• During late spring and summer use whatever water is available to fill the highest priority southern bell frog wetlands. (Core southern bell frog wetlands are listed in Appendix D.) • For waterbirds, provide water to maintain initiated small-scale bird breeding events. If there is water available use this to avoid damage to as many sites as possible, in conjunction with watering for southern bell frog. • Water traded in from the Murray River, or carryover, could also be used to inundate key areas.	• Maintain in good condition as many known southern bell frog sites and colonial nesting waterbird sites as possible. • Use carryover volumes to maintain follow-up watering.	• Provide maintenance flows to key waterbird rookeries which may establish in Yanga National Park. • Inundate key rookeries and other wetlands of the Nimmie-Caira system, creating and sustaining a waterbird breeding event. Requires 60,000–70,000 ML. • Inundate larger southern bell frog wetlands in the Lowbidgee (Maude and Redbank systems) to facilitate significant distribution of the population. (e.g. Eulimbah Swamp requires 6,000 ML, Twin Bridge requires 4,000 ML.) • Inundate prioritised sections of privately owned river red gum forest/woodland and Lignum creeks/swamps in the Lowbidgee from both Redbank and Maude Weirs. Requires approximately 50,000–60,000 ML. • Inundate the northern section of river red gum forest in Yanga National Park (above Tala Lake). Requires approximately 60,000 ML. • Inundate southern sections of river red gum forest in Yanga National Park (south of Tala Lake) using the channel systems from Maude Weir to greatest efficiency, and through flows from North Yanga (which may have more environmental benefit). Requires approximately 50,000–60,000 ML.	• Maintain and complete any southern bell frog and colonial waterbird breeding events initiated by natural flood event or environmental flows. • Maintain river-floodplain connectivity initiated by natural flood events or environmental flows. • Inundate the Lowbidgee wetlands and river red gum forest north of Redbank Weir to Balranald. Requires approximately 100,000 ML. • Inundate extensive areas of the Yanga Nature Reserve and other significant wetlands located outside the Lowbidgee Flood Control and Irrigation District (e.g. Yanga Lake). Requires approximately 100,000 ML.

Environmental Asset	Management objectives for specific water availability scenarios			
	Extreme Dry	Dry	Median	Wet
	Goal: Avoid damage to key environmental assets	Goal: Ensure ecological capacity for recovery	Goal: Maintain ecological health and resilience	Goal: Improve and extend healthy and resilient aquatic ecosystems
Yanco Creek system	• No options—requires median levels of water availability.	• No options—requires median levels of water availability.	• Inundate extensive areas of Wanganella Swamp to maintain or improve semi-permanent aquatic communities to good condition. • Inundate extensive areas of Wanganella Swamp to encourage colonial waterbird breeding event, holding some water in reserve if needed to complete the breeding event. • Requires 1,500 ML to inundate 470 ha of Wanganella Swamp (Webster & Davidson 2010). • Inundate Forest Creek and associated downstream wetlands, creating an end-of-system flow to Moulamein.	• Maintain and complete any colonial waterbird breeding events initiated by natural flood event or environmental flows. • Maintain and complete any fish movement events initiated by natural flood events or environmental flows.

** Translucent flows from Burrinjuck and Blowering Dams do not persist in the Murrumbidgee River system below the confluence with Tumut River.*

^ Piggybacked flows in the Murrumbidgee River will also inundate assets in the northern Yanco Creek catchment.

 # Supplementary water is only available when a supplementary event is declared by NOW.

4. Water Use Framework

Water resource requirements for ecological assets, and operating regimes to meet these, are presented in this chapter. If information describing the general context of an asset exists, providing a basic description of its ecological watering requirements is an interpretation of the combined watering needs of the dominant freshwater-dependent vegetation communities, and known and expected fauna, bearing in mind the natural, historic and prevailing watering regime and current use, and the desired ecological condition. Describing the same regime in hydrological terms to provide a foundation for creating an operational delivery strategy to satisfy those ecological requirements is often harder. This is because the flow characteristics of some areas of the Murrumbidgee River catchment have been better quantified than others. Hence, the following uses the best available information to describe the volume requirements to meet ecological watering requirements at various assets in the Murrumbidgee River catchment.

4.1 Overview of the Murrumbidgee River operating environment

The Murrumbidgee is a heavily regulated river with 26 dams as well as weirs and irrigation canals. Storages include those in the Snowy Mountain Hydro-electric scheme, those forming the Australian Capital Territory Water Supply System and the major New South Wales irrigation dams (Blowering Dam and Burrinjuck Dam) (CSIRO 2008). The Murrumbidgee River includes seven weirs that are used to manage water levels for diversion. These are Berembed, Yanco, Gogeldrie, Hay, Maude, Redbank and Balranald Weirs. The weirs contain relatively small storage volumes (1,000 to 13,000 megalitres) and have limited capacity for re-regulation of flow. There is also an off-river en-route storage (Tombullen) with a capacity of 11,000 megalitres that offers limited re-regulation opportunity.

Most of the flow in the Murrumbidgee River comes from the upper portion of the catchment, and is delivered by the main tributary rivers: Yass, Molongolo, Queanbeyan, Bredbo, Numerall, Cotter, Goodradigbee and Tumut (Kingsford & Thomas 2001). Several tributaries located immediately downstream of the dams contribute significant inflows, including Adelong, Adjungbilly, Gilmore, Hillas, Tarcutta, Kyeamba, Jugiong, Muttama, Billabong and Houlghans Creeks, and Goobaragandra River. The middle and lower portions of the catchment do not contribute significant inflows.

The average surface water availability in the Murrumbidgee is 4,270 GL/yr with approximately one tenth sourced from inter-basin transfers from the Snowy Mountains Hydro-electric scheme (CSIRO 2008). This is an average amount, so there is capacity to retain more water during wet years. The Regulated Murrumbidgee River has a long-term extraction limit of 1,890 GL/yr, thus approximately 57 per cent of the mean annual flow contributes to maintenance of basic ecosystem health (WSP 2003). In the 2009–10 financial year there were approximately 1,888,070 general security shares, 356,846 high security shares and 198,779 supplementary shares in the Regulated Murrumbidgee (Green et al. 2011). Details of these and other entitlements are provided in Table 5.

The Murrumbidgee and Coleambally irrigation areas are located downstream of Wagga Wagga and are responsible for approximately three quarters of the irrigation diversions. River pumpers and private irrigation schemes are located further downstream. The MIA is supplied by the Main Canal which diverts water from the Berembed Weir pool and Sturt Canal which diverts water from the Gogeldrie Weir pool. The Coleambally Irrigation Area is also supplied by a canal which diverts water from the Gogeldrie Weir Pool. Flows into Yanco Creek are regulated by Yanco Weir. Diversions into the Nimmie-Caira portion of the Lowbidgee wetland are taken from the Maude Weir pool, while diversions into South and North Redbank are taken from the Redbank Weir Pool.

Table 5: Summary description of entitlement characteristics in the Murrumbidgee River catchment. (Source: WSP 2003, NOW Water Access Licence Statistics available online^)

Licence Type	Purpose	Quantity Types	ML/year or Unit Shares (In WSP)*	ML/year or Unit Shares (in 2009–10 licence register)	Number of Licensees (2009–10)	Water Determination Period Announcement	Basis of Diversion
Stock and Domestic and Native Title Rights	Fulfilment of basic landholder rights	Volume	35,572	35,937.9	478	Annual	System must be managed so that if worst historical inflow occurs 100% of volume can be supplied.
Local Water Utility Access	Town water supply	Volume	23,403	23,586	14	Annual	System must be managed so that if worst historical inflow occurs 100% of volume can be supplied.
High Security	High reliability demands such as permanent plantings, cultural, research and some town water supply	Unit Share	298,021	377,435	169	At periods less than or equal to a month, unless 1 ML/unit share	System must be managed so that if worst historical inflow occurs, 0.95 ML/unit share can be supplied.
General security	Low reliability demands such as annual cropping	Unit share	2,043,432	1,888,069.7	795	At periods less than or equal to a month, unless 1 ML/unit share	High security licences must be supplied with a minimum of 0.95 ML/unit share before general security is supplied.
Murrumbidgee Irrigation Conveyance	Provision for conveyance losses in the MIA canals	Unit share	243,000	243,000	2	As required	Based on general security water determination.
Coleambally Irrigation Conveyance	Provision for conveyance losses in the CIA canals	Unit share	130,000	130,000	2	As required	Based on general security water determination.
Regulated River Conveyance	Unknown	Unit share	–	2,968	2		Unknown
Supplementary	Volumes available when other environmental and licence uses are satisfied	Unit share	220,000	198,779.8	227	Annual	Supplementary events announced depending on the conditions that arise during the year.

** Shares in the Water Sharing Plan differ to the 2009/10 licence register owing to both licence conversion and trading of shares.*

^ At http://wma.naturalresources.nsw.gov.au/wma/WALStatisticsSearch.jsp?selectedRegister=WALStatistics

4.1.1 Murrumbidgee River (including the Lowbidgee Floodplain)

Below the Murrumbidgee River at Wagga Wagga there are seven storages and one re-regulating structure: Berembed, Yanco, Gogeldrie, Hay, Maude, Redbank and Balranald Weirs, and Tombullen off-river storage (Shields & Good 2002). In addition to these dams and weirs there are thousands of kilometres of delivery and drainage canals and channels. Table 6 provides an operational summary of the major dams and weirs in the Mid-Murrumbidgee and Lowbidgee areas.

The two dams, seven weirs and Tombullen Storage are operated by State Water Corporation (SWC) to meet customer orders. Since the weirs and Tombullen have relatively small storages, most orders are supplied by releases from either of the two dams and customers are required to place orders sufficiently early to allow for the travel time to their diversion structure, plus one-day processing time. Any transmission losses between the dams and the customer's diversion structure are owned by SWC.

Table 6: Water storages and weirs in the Murrumbidgee, Lowbidgee and Yanco systems. [1]

Name	Description	Operation	Associated Assets
Blowering Dam	Located on the Tumut River, which is a major tributary of the Murrumbidgee River. Regulates approximately 87 per cent of all inflows (CSIRO 2008). Stores both natural flows and waters released from the Snowy Mountains Hydro-electric scheme.	• 1,628 GL capacity (Green et al. 2011). • On average 1,460 GL/yr released into the Tumut River which then enters the Murrumbidgee River. • There is a 9,300 ML/d flow constraint at Tumut[1] to avoid erosion thresholds in the channel downstream and localised flooding. This is also the maximum release capacity at full supply level.	• All assets downstream of the dam on the Murrumbidgee River and Tumut Rivers.
Burrinjuck Dam	Located on the Murrumbidgee River. Burrinjuck Dam regulates approximately 77 per cent of all inflows (CSIRO 2008).	• 1,026 GL capacity (Green et al. 2011). • On average 1,510 GL/yr released into the Murrumbidgee River. • Maximum release rate at full supply level is 29,100 ML/d. • There is a 32,000 ML/d constraint at Gundagai[1].	• All assets downstream of the dam on the Murrumbidgee River.
Berembed Weir	Located on the Murrumbidgee River 60 km downstream of Wagga Wagga, Berembed Weir supplies the MIA's Main Canal. Diverts approximately 6,400 ML/d along the Main Canal (Shields & Good 2002). The Main Canal carries approximately 80 per cent of all water which is diverted for irrigation purposes in the MIA (Shields & Good 2002). This structure is primarily used for irrigation diversions, and is not a storage structure.	• Maximum capacity of 6,700 ML/d to the Main Canal (Green et al. 2011).	• Lower Mirrool Creek Floodplain • Barren Box Swamp • Fivebough Swamp • Tuckerbil Swamp • Selected Mid-Murrumbidgee wetlands
Bundidgerry Creek	Bundidgerry Creek supplies water to MIA from the Murrumbidgee River. Water flows through the Bundidgerry Creek system from Berembed Weir to a regulator owned and operated by MIA, 8 km upstream from Narrandera. Water released from MIA's regulator flows through the Lake Talbot complex before passing MIA's meter at Narrandera. Note that Main Canal and Bundidgerry Creek are the same waterbody.	• Maximum regulated capacity of 4,300 ML.	• Lower Mirrool Creek Floodplain • Barren Box Swamp • Fivebough Swamp • Tuckerbil Swamp • Selected Mid-Murrumbidgee wetlands

1 'State Water Corporation – Water Supply Work Approval, Murrumbidgee Regulated River Water Source' issued by the NSW Office of Water 2011.

Name	Description	Operation	Associated Assets
Yanco Weir	Located on the Murrumbidgee River approximately 15 km downstream of Narrandera. Yanco Weir is not strictly a storage facility for reregulation; its primary role is to raise the Murrumbidgee River level to above the Yanco Creek sill so that flows occur in Yanco Creek. More details on the operation of the Yanco Creek System are provided in Section 4.1.3.	• Maximum capacity of 1,400 ML/d to Yanco Creek1. • Diverts 290,000 ML annually from the Murrumbidgee to the Yanco, Colombo and regulated Billabong Creek systems.	• Yanco Creek system • Colombo Creek system • Billabong Creek system • Wanganella Swamp • Selected Mid-Murrumbidgee wetlands
Tombullen off-river storage	The Tombullen off-river storage acts as a re-regulation storage to reduce losses of up to 50,000 ML/year by storing surplus which is then released for use downstream as required (Shields & Good 2002). Historical releases range from under 100 ML/d to 1,600 ML/d (MDBC 2008).	• 10,880 ML capacity • Murrumbidgee River water stored for later release.	• Can be used to enhance peak height and duration during piggybacking events downstream of Gogeldrie.
Gogeldrie Weir	Located on the Murrumbidgee River 30 km downstream of Yanco Weir (between Narrandera and Hay). Gogeldrie Weir controls flows into the MIA's Sturt Canal and the Coleambally Main Canal that supplies the CIA and helps fill the Tombullen off-river storage. Flows at Gogeldrie Weir can also be diverted into the Yanco Creek system, via the Coleambally Irrigation system.	• Maximum capacity of 4,471.5 ML. • Diverts 5,500 ML/d to the Colleambally Canal and Sturt Canal.	• Yanco Creek System • Barren Box Swamp • Lower Mirool Creek Floodplain • Selected Mid-Murrumbidgee wetlands • Coonancoocabil Lagoon and Swamps
Hay Weir	Hay Weir is a re-regulatory structure that captures surplus flow downstream Gogeldrie Weir. It buffers downstream users against problems with the timing of supply (water can take up to 15 days to reach Hay from the headwater storages) (Green et al. 2011).	• 12,900 ML capacity. • Channel capacity is 35,000 ML/d.	
Maude Weir	Controlled flood flows from the Maude weir are provided to the Nimmie-Pollen Creeks and Caira systems and associated wetlands, which can supply water to the southern portion of Yanga	• Maximum capacity is 4,760 ML. • Provides controlled flow and over bank flow to the Lowbidgee Floodplain. • Channel capacity is 20,000 ML/d.	• The Nimmie-Caira state-protected wetlands and floodways.

Name	Description	Operation	Associated Assets
Redbank Weir	The Redbank system lies to the west of Nimmie-Caira and Fiddlers-Uara systems, and borders the Mallee country to the west. The system is divided into Redbank North and Yanga (divided by the Murrumbidgee River). Flows are generally delivered to both areas via Redbank Weir, but the northern and southern banks are managed separately (SKM 2008). Water is delivered to North Redbank through Juanbung regulator, and the North Redbank channel and associated offtake regulators. Water can be diverted to Yanga through Yanga (IAS) and Waugorah (IES) regulators. The southern portion of Yanga can also be supplied from the Nimmie-Caira system via Tala Lake.	• Channel capacity is 11,000 ML/d.	• Yanga National Park and the wetlands of the North Redbank system. • Tala Creek • River red gum forests interspersed with swamps (Kingsford & Thomas 2001). • Yanga wetlands • Uara creek • Murrumbidgee Valley Nature Reserve (formerly Yanga Nature Reserve)
Balranald Weir	Balranald Weir is a drop-board structure 40 m long and 3.7 m high, located 6 km west of the Balranald township (Baumgartner 2004). The weir is primarily used for town water and stock and domestic water supply. When the Murrumbidgee River reaches Balranald Weir, flows are primarily confined to the main channel before eventually flowing into the Murray River (Kingsford & Thomas 2001).	• Historical releases range from under 100 ML/d to 1,600 ML/d (MDBC 2008). • Channel capacity is 6,500 ML/d. • Once flows exceed 2,000 ML/d, drop-boards are progressively removed such that when the flow reaches 4,000 ML/d all boards are removed and free passage is restored (E Taylor (SWC) 2011, pers. comm., 28 October).	• Floodplain wetlands downstream of Balranald. • Murrumbidgee River channel

4.1.2 Murrumbidgee Irrigation Area (Mirrool Creek System)

The drainage network in the MIA is extensive, consisting of over 2,160 kilometres of channels (Roberts et al. 1998) (Figure 7).

Fivebough Swamp, Tuckerbil Swamp, Barren Box Swamp and Mirrool Creek are all located within the MIA. Delivery of environmental water to these assets requires use of supply and/or drainage canals operated by MI. Transmission losses incurred in delivering water to environmental assets within the irrigation area would be accounted against the environmental water manager. Losses are estimated to range from 10 to 30 per cent depending upon the antecedent conditions (these are advised by Murrumbidgee Irrigation Services at the time). Canals in the MIA are generally closed for maintenance in the months of May and June. It is expected that there will only be limited capacity to supply environmental assets during the peak irrigation season from November to February.

Prior to water resource development, Barren Box Swamp was a natural depression on Mirrool Creek covering an area of 3,200 hectares (MI 2008). As irrigation developed, Barren Box Swamp was impounded by levee construction to protect the surrounding land from flooding and to act as a storage basin for downstream irrigation supply. The Barren Box Storage system acted as offline storage for drainage water from the Mirrool and Yanco Irrigation Areas. Water arriving at Willow Dam that exceeded the Wah Wah Irrigation District demand would also be diverted into the storage for later delivery. In the event the swamp storage was full, flood waters would be transferred to the Lower Mirrool Creek floodway through the Barren Box Outfall Channel (MI 2008).

Barren Box Swamp has since been redeveloped into three basins or 'cells' through the use of levee banks. The Active and Intermediate Cells have been designed for use as water storages while the Wetland Cell has been set aside for wetland rehabilitation (MI 2008). Following redevelopment, the Barren Box storage operates in a similar manner (as an offline storage basin), however as it operates as three storages there is additional complexity to the operating rules.

Fivebough Swamp is a natural inland drainage depression within the MIA (Fivebough & Tuckerbil WMT 2002). There are five regulatory structures on the contour drain around the swamp which enables water to pass from the drain into the swamp (Fivebough & Tuckerbil WMT 2002). The swamp is used for treated effluent discharge from Leeton Sewerage Treatment Plant. This inundates the central west portion throughout the year.

Tuckerbil Swamp is a natural drainage depression which forms part of a natural drainage line from Fivebough Swamp through Tuckerbil and north-west to Mirrool and Little Mirrool Creeks. There are two regulatory structures on drains which pass through the southern end of Tuckerbil Swamp. During periods of heavy rainfall, MI diverts large volumes of drainage water into the swamp to alleviate flooding further downstream (Glazebrook & Taylor 1998 cited in Fivebough & Tuckerbil WMT 2002).

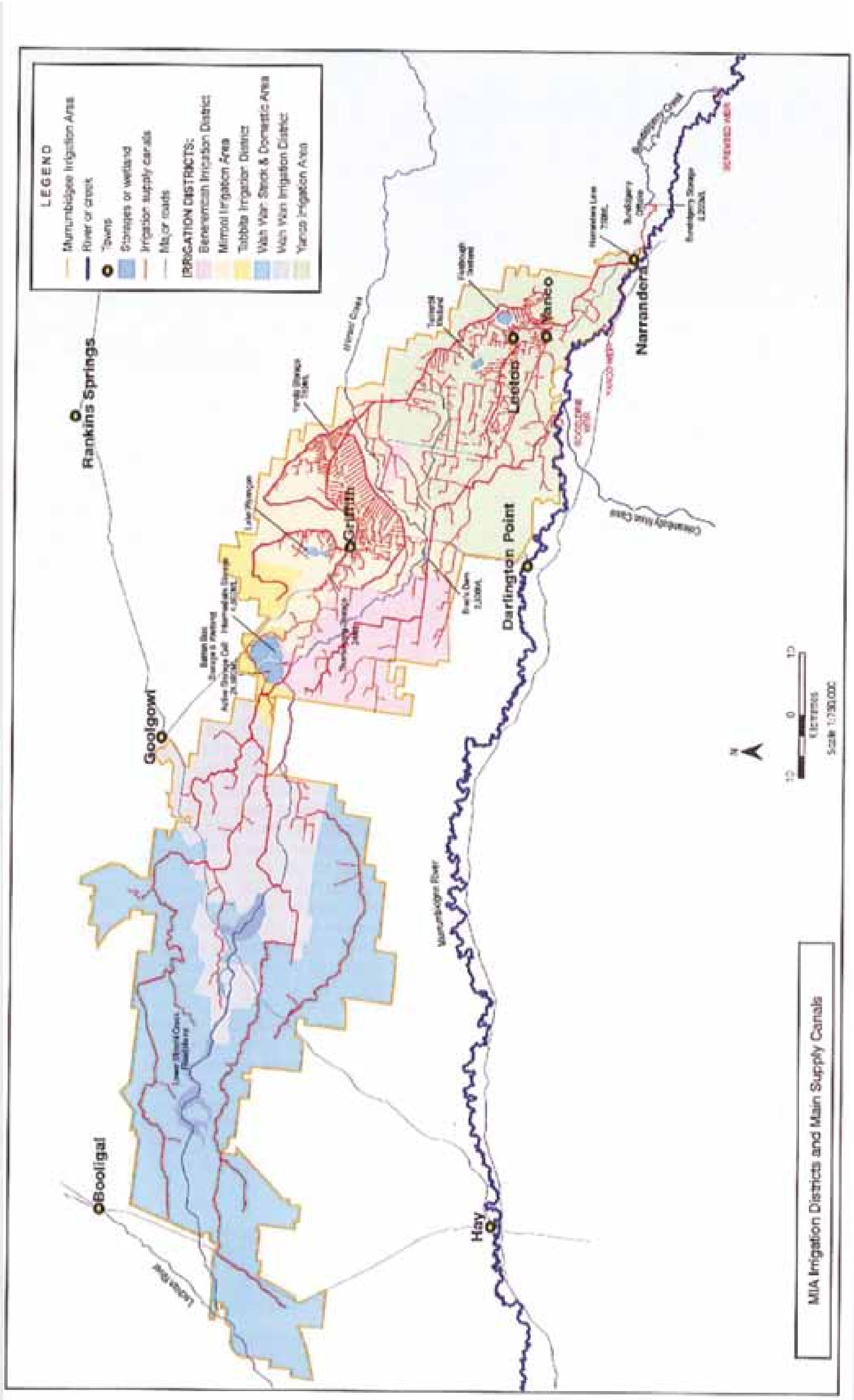


Figure 7: Murrumbidgee Irrigation Area and the Mirrool Creek catchment. (Source: MI 2007)

4.1.3 Yanco Creek System

Yanco Creek flows from the Murrumbidgee River to its junction with Billabong Creek near Conargo. Colombo Creek is an effluent of Yanco Creek that is located some 50 kilometres downstream from the Yanco Creek Weir at the Murrumbidgee River. The Colombo system takes a mostly southerly flow-path where it joins the Billabong Creek upstream of Jerilderie. Billabong Creek meets the Edward River at Moulamein, which flows into the Wakool River and eventually the Murray.

The Forest Creek system is an anabranch of Billabong Creek and consists of a number of creeks including Forest Creek, Eight Mile Creek, Box Creek, Estuary Creek and the Forest Anabranch. Water is diverted out of Billabong Creek into Forest Creek at the Forest Creek Regulator part of Hartwood Weir pool to supply irrigators at the upper end of Forest Creek. The Forest Creek system upstream of Warriston Weir is a regulated watercourse and part of the Murrumbidgee Regulated Water Source (Webster & Davidson 2010). Downstream of Warriston Weir is unregulated with only high flows and flood flows passing this point (Dalton & Clark 2009).

Flows entering the top end of the Yanco Creek system at Murrumbidgee typically take four to five weeks to reach the Edward River (Dalton & Clark 2009). Flows in Yanco Creek can be supplemented by both managed flows and inflows from the Western Colleambally Channel (which flows into Billabong Creek downstream of Wanganella). Similarly, flows in Billabong Creek can be supplemented through the Murray Irrigation Limited Finley Escape (Beal et al. 2004).

4.2 General operational information

A schematic depicting the location of dams, regulators and weirs in the Murrumbidgee River catchment is provided at Figure 8. Figure 9 provides further information on the operational environment of Tumut River and the Yanco Creek system.

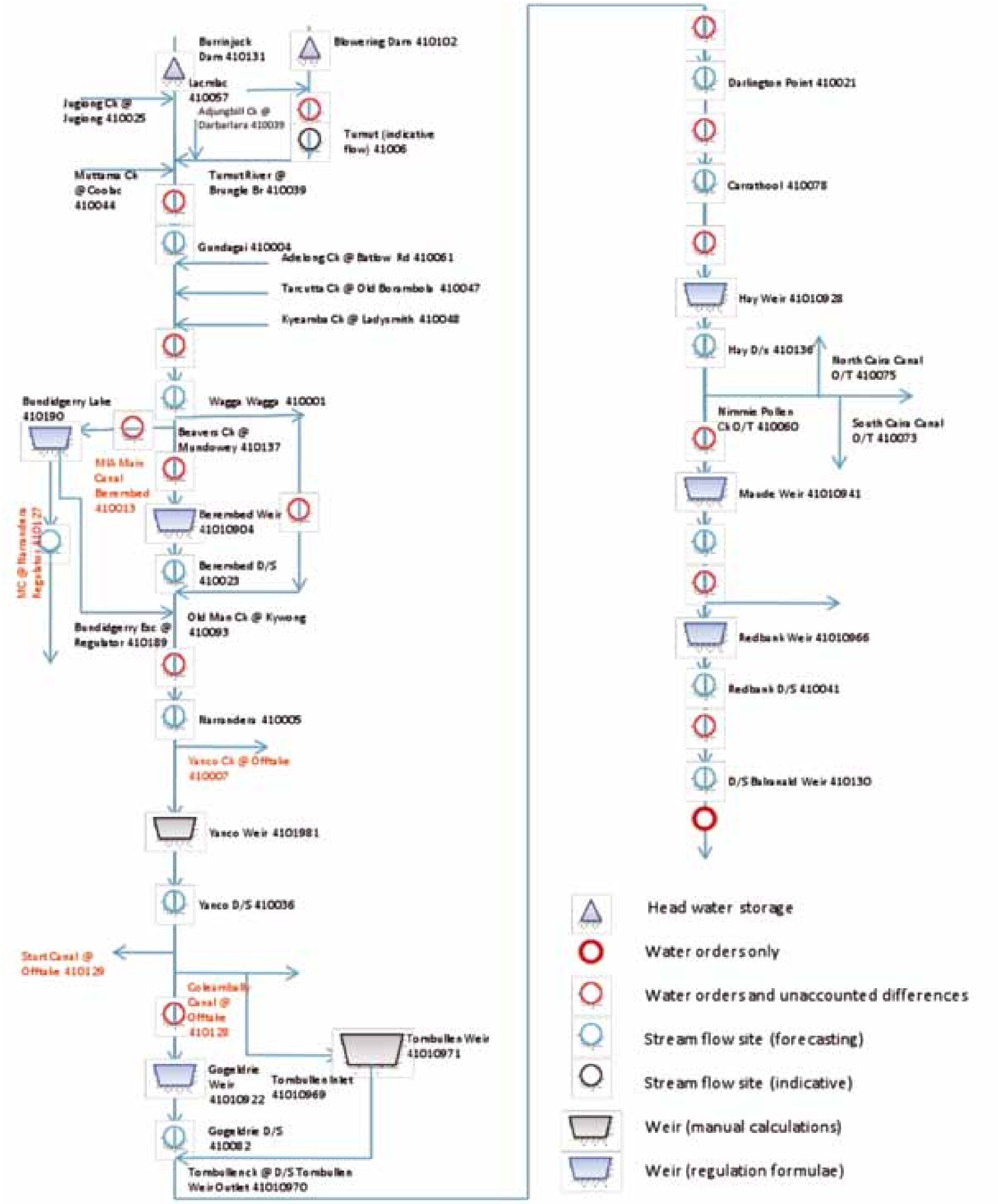


Figure 8: Schematic of the location of dams, regulators and weirs in the Murrumbidgee River catchment.

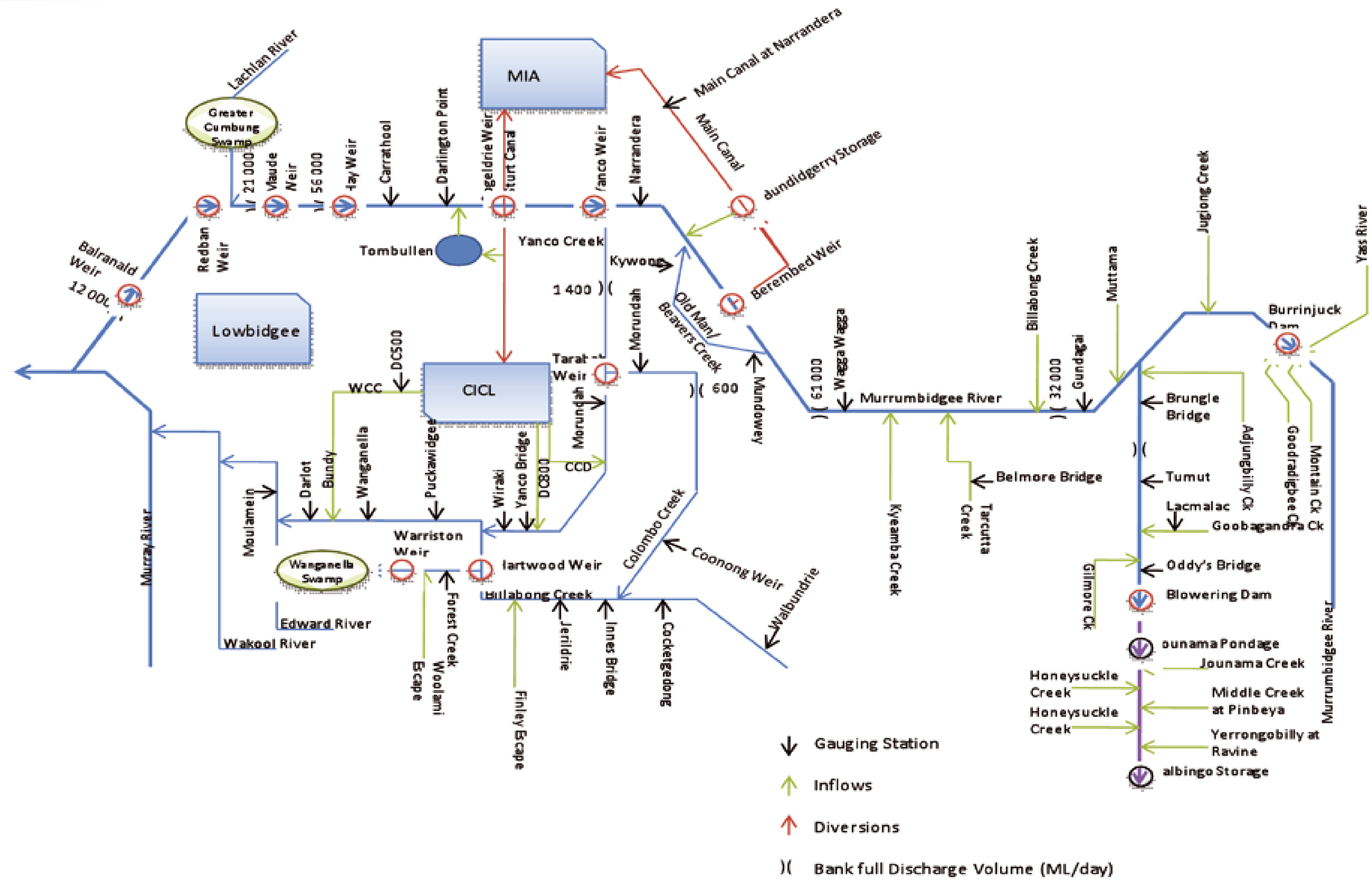


Figure 9: Schematic of the Tumut River and the Yanco Creek system operational environment.

4.2.1 Murrumbidgee River flow monitoring sites

There is a relatively comprehensive hydrometric gauge network within the Murrumbidgee River and its tributaries which is operated by the NSW Office of Water (Table 7). The main river channel has gauges at regular intervals, many of which were in operation before the 1970s. In addition, all major tributaries upstream of Wagga Wagga have gauged sites, although the length of record is generally much shorter and less reliable than the main river sites.

Hydrometric flow gauges along the Murrumbidgee River are located at D/S Burrinjuck Dam (410008), Gundagai (410004), Wagga Wagga (410001), D/S Berembed Weir (410023), Narandera (410005), D/S Gogeldrie Weir (410082), Darlington Point (410021), Carrathool (410078), D/S Hay Weir (410136), D/S Maude Weir (410040), D/S Redbank Weir (410041) and D/S Balranald Weir (410130). There are several gauges on the Tumut River but the most relevant is the gauge at Tumut (410006), just downstream of Blowering Dam. There are also many gauges on the Yanco system, with the most relevant being Yanco Creek at the offtake (410007), Yanco Creek at Yanco Bridge (410169), Billabong Creek at Jerilderie (410016) and Billabong Creek at Darlot (410134). The gauge at Darlot measures end-of-system flows that discharge into the Edward-Wakool system. Three gauges which measure diversions into the Nimmie-Caira section of the Lowbidgee wetland are Caira Creek at Offtake (410173), Nimmie Pollen Creek at Offtake (410060) and North Caira main canal at Offtake (410175). Historical flow data for these stations can be obtained from the Hydsys (or hydstra) hydrometric archive which can be purchased from the NSW Office of Water. Real-time data is available at http://waterinfo.nsw.gov.au/.

In 2009, OEH installed acoustic doppler flow meters downstream of the Yanga and Waugorah regulators, which control diversions into Yanga National Park. They also installed flow meters and depth loggers in key wetlands in Redbank North, Yanga, the Uara Creek section of Yanga, and in the three major creeks that deliver water from the Nimmie-Caria system into the southern half of Yanga. As of late August 2011 streamflow gauging stations were installed just downstream of the Glen Dee regulator, and another just upstream of the Athen regulator (in North Redbank channel) (James Maguire (OEH) 2011, pers. comm., 9 August).

Diversions into the MIA are measured by gauges at Main Canal at Narrandera and the Stuart Canal Offtake off the Gogeldrie Weir pool. These gauging stations and others within the MIA are operated by MI.

It should be noted that Table 7 does not provide an exhaustive list of gauges in the catchment.

Table 7: Streamflow gauging stations in Murrumbidgee River catchment.

Gauge	Number	Stream	Comments
Gauges on main stem of Murrumbidgee River			
D/S Burrinjuck Dam	410008	Murrumbidgee	Releases from Burrinjuck
Gundagai	410004	Murrumbidgee	Informs flow augmentation—threshold of flooding
Wagga Wagga	410001	Murrumbidgee	Informs flow augmentation—threshold of flooding
D/S Berembed	410023	Murrumbidgee	Monitors flow augmentation
Narrandera	410005	Murrumbidgee	Monitors flow augmentation
D/S Gogeldrie Weir	410082	Murrumbidgee	Monitors flow augmentation
Darlington Point	410021	Murrumbidgee	Monitors flow augmentation
Carrathool	410078	Murrumbidgee	Monitors flow augmentation
D/S Hay Weir	410136	Murrumbidgee	Monitors flow augmentation
D/S Maude Weir	410040	Murrumbidgee	Monitors the river downstream of Lowbidgee diversions
D/S Redbank Weir	410041	Murrumbidgee	Monitors the river downstream of Lowbidgee diversions
D/S Balranald Weir	410130	Murrumbidgee	End of system flows—to Murray system
Tributaries			
Tumut	410006	Tumut	Releases from Blowering Dam
Yanco Cr at offtake	410007	Yanco Creek	Diversions to Yanco system
Yanco Bridge	410169	Yanco Creek	Internal flows
Jerilderie	410016	Billabong Creek	Internal flows
Darlot	410134	Billabong Creek	Outflows to Edward/Wakool in Murray system
Lowbidgee*			
Caira Creek offtake	410173	Caira Creek	Diversions to Nimmie-Caira system
Nimmie/Pollen offtake	410060	Pollen Creek	Diversions to Nimmie-Caira system
Nth Caira offtake	410175	Nth Caira Canal	Diversions to Nimmie-Caira system
Regulator 1AS	41000246	Yanga Creek	Main diversion channel into Yanga—New
Regulator 1ES	41000240	Waugorah Cr	Secondary diversion into Yanga—New
Diversions to MIA Wetland Assets			
Berembed offtake	410013	Main Canal	Diversions into the Main Canal/Bundidgerry Creek
Narrandera Regulator	410127	Main Canal/ Bundidgerry	Diversions from Main Canal/Bundidgerry Creek into irrigation districts
Gogeldrie offtake			Diversions into the Sturt Canal

* *Note: The regulators that control flows into North Redbank are not gauged.*

4.2.2 Murrumbidgee River travel times

The time taken for flows to pass down the Murrumbidgee River varies, depending upon the flow magnitude, but typical travel times under regulated flow conditions are provided in Table 8. Note that actual travel times vary depending on the amount of flow in the river. Travel times will generally be shorter during periods of high flow, and longer in periods of minimum flow.

Table 8: Approximate travel times in Murrumbidgee River. (Source: Bewsher Consulting 1996; Olive & Olley 1997; Beal et al. 2004)

Reach	Comments	Days	Cumulative
Main Stem of the Murrumbidgee			
Dams to Gundagai		1	1
Gundagai to Wagga	Start of Mid-Murrumbidgee wetlands	1	2
Wagga to Berembed	Main offtake to MIA	2	4
Berembed to Narrandera		1	5
Narrandera to Gogeldrie		1	6
Narrandera to Yanco Weir	Offtake to Coleambally Irrigation Area	0.5	6.5
Gogeldrie to Darlington Point		1	7.5
Darlington Point to Carrathool	End of Mid-Murrumbidgee wetlands	2.5	10
Carrathool to Hay Weir		3	13
Hay Weir to Maude Weir	Offtake to Nimmie Caira (Lowbidgee Floodplain)	1.5	14.5
Maude Weir to Redbank Weir	Offtake to North Redbank and Yanga	2	16.5
Redbank Weir to Balranald	End system discharge to Murray River	3.5	20
MIA			
Main Canal offtake to Barren Box Swamp		6	6
Sturt Canal offtake to Barren Box Swamp		4	10
Yanco Creek			
Dams to Yanco offtake	Yanco Creek	7.5	7.5
Yanco offtake to Tarabah Weir	Yanco Creek	2.5	10
Morundah to Yanco Bridge	Yanco Creek	7	17
Yanco Bridge to Puckawidgee	Yanco Creek	7	24
Tarabah Weir to Innes Bridge	Colombo Creek	8	--
Innes Bridge to Jerilderie	Billabong Creek	2	--

Reach	Comments	Days	Cumulative
Jerilderie to Hartwood Weir	Billabong Creek	4	--
Hartwood Weir to Conargo	Billabong Creek	1.5	--
Conargo to Darlot	Billabong Creek	7	28
Darlot to Moulamein	Billabong Creek (end of system to Edward River)	7–10	53.5–56.5
Forest Creek off-take to Warriston Weir	This is included as an indication for flows in Forest Creek.	5–6	--
Lowbidgee			
Nimmie-Caira offtake to Tala Lake	Through Nimmie-Caira to Yanga.	10	10
Yanga offtake to Lake Tala	Through Yanga.	5–10	15–20

4.2.3 Storage releases

Blowering Dam has a maximum release capacity of 9,300 ML/d at full supply level, whilst Burrinjuck Dam has a maximum release capacity of 29,100 ML/d at full supply level. The release capacities for both dams reduce as water levels fall. Below 40–45 per cent there is a significant reduction in the ability to release flows at the release capacity. The works target is 32,000 ML/d at Gundagai.

4.2.4 River channel capacity

The capacity of the main channel of the Murrumbidgee River reduces in a downstream direction, as follows:

- Hay, 35,000 ML/d
- Maude, 20,000 ML/d
- Redbank, 11,000 ML/d
- Chaston's Cutting, 8,000 ML/d
- Balranald, 11,000 ML/d.

4.2.5 Release initiation planning

Prior to the initiation of each release, formal notification to OEH is required. Arrangements to transfer water from the environmental water licences to the appropriate NSW delivery partner must also be confirmed. Water orders are then lodged with SWC, which manages the physical delivery.

4.3 MIA system

4.3.1 Water resource requirements

4.3.1.1 Fivebough Swamp

The primary objective for environmental watering at Fivebough Swamp is to maintain suitable habitat for migratory and local waterbirds. Prior to irrigation development, the swamp filled via local run-off during winter and spring then dried out over summer due to evaporation and infiltration. Management of the wetland is targeted at supporting the annual wet/dry sequence (except for areas of permanent inundation associated with the discharge of treated sewage effluent from Leeton sewage treatment plant). A volume of 500 megalitres is required to inundate the swamp (approximately 60 per cent of the swamp is inundated by 500 megalitres), with the last managed event occurring in early 2010.

Fivebough Swamp has four management zones (which are contiguous) (Fivebough & Tuckerbil WMT 2002):

- Zone 1 (eastern portion)—covers approximately 60 per cent of the swamp and requires inundation to a depth of 45 centimetres in eight out of 10 years (Biosis Research & WI-O 2006)
- Zone 2 (western portion)—requires shallow water (i.e. 3 centimetres) inundation in nine out of 10 years (Biosis Research & WI-O 2006). A portion of Zone 2 is continually wet from irrigation of treated sewage effluent
- Zone 3 (entrance area)—predominantly dry zone that does not have ecological water requirements
- Zone 4 (north-western portion)—is an ephemeral wetland favoured by larger wading birds. The water management objective is to support temporary wetlands, but the volumes of water required to achieve this are not known. Water enters this area via an escape during high rainfall events or via Zone 1 when water levels are sufficiently high in winter and spring.

Current management of Fivebough Swamp opens the southern regulatory structure on the contour drain from June until November to allow natural rainfall run-off to enter the wetland. The Fivebough and Tuckerbil Swamps Management Plan notes that the length of time varies depending on the season.

Artificial watering of the swamp has been undertaken using water supplied from the Murrumbidgee River through the MI supply channels. The optimum time for this to be undertaken from a delivery aspect is between July to October. This is the low-regulated season and is after the annual maintenance period in the MIA channels. Water for managed events would be supplied via Murrumbidgee Irrigation’s supply channels, which requires liaison with MI.

4.3.1.2 Tuckerbil Swamp

Tuckerbil Swamp is a natural inland drainage depression covering 289 hectares. The objective for the management of Tuckerbil Swamp is to maintain and protect habitats for migratory shorebirds, and other waterbirds including threatened species. Prior to irrigation development, the swamp was filled by local run-off during winter and spring then dried out over summer due to evaporation and infiltration. A key management goal for the wetland is to support the annual wet/dry sequence.

The watering objective is for inundation to a depth of at least 30 centimetres in five out of ten years (DEC 2006). A volume of approximately 500 megalitres is required to fill the swamp.

Inundation from the local catchment generally occurs between June and November. As with Fivebough Swamp, the optimum time for delivery of managed events in dry years is from July to October.

4.3.1.3 Barren Box Swamp

Barren Box Swamp incorporates three water-management basins, or cells, separated by levee banks. Two of these cells are used for the collection and redistribution of drainage water to downstream users, in the Wah Wah District or in Lower Mirrool Creek. The third cell (the 'Wetland Cell') is a wetland and terrestrial rehabilitation site being managed to support black box woodland. Rehabilitation plans for this cell also include rehabilitation of grassy woodland/ chenopod shrubland (MI 2008).

The Wetland Cell has an area of 1,650 hectares comprising approximately half of the total swamp area (MI 2008). It has two main vegetation communities based on the frequency of inundation. The inner zone has an area of 320 hectares and supports black box grassy open woodland. The watering objectives for this zone are:

- annual flows in winter/spring for first three years post-planting for plant establishment (planting commenced in 2010)
- post-plant establishment, the optimum frequency of inundation is between two and five years; with an inter-annual dry period of two to four years. However, this zone may tolerate periods of seven to 10 years between watering events. The optimum duration of inundation is 35 to 60 days, however this zone can be inundated for a period of up to one year
- a volume of approximately 250 to 610 megalitres (depending on the antecedent conditions) is required to inundate this inner zone.

Beyond this 'wetter' area is a 1,230-hectare terrestrial zone that will be inundated infrequently from large floods in Mirrool Creek. No specific watering requirements are proposed for the terrestrial zone because this area will be managed to support a terrestrial community, and as such has no watering goals.

4.3.2 Operating regimes

Mirrool Creek flows into Willow Dam upstream of Barren Box Swamp. From Willow Dam, water can be sent into Barren Box Swamp or into the Wah Wah channel. Flow from the Wah Wah channel can be directed into the Lower Mirrool Creek Floodplain through a regulator. Water can also be supplied to the floodway directly from Barren Box Swamp. Fivebough Swamp is not inundated by flows in Mirrool Creek and relies on local run-off or managed flows. Tuckerbil Swamp can be watered via the Murrumbidgee Irrigation drainage network.

Supply of managed environmental water from the Murrumbidgee River to assets in the MIA is via the MI supply channels. Water is delivered into the MI system at Berembed Weir. The optimum time for delivery of managed events is either September/October (i.e. immediately prior to peak irrigation demand) or March/April (i.e. immediately after the peak irrigation demand). During this period the system is shut down for maintenance. Although it is worth noting that the volumes required for Fivebough Swamp and Tuckerbil Swamp are small and can most likely be delivered during the irrigation season.

Water from Burrinjuck or Blowering Dam to Bundidgerry offtake takes approximately five days to deliver, however, MI orders are placed seven days in advance. Travel time from Bundidgerry offtake to Barren Box is approximately eight to nine days.

Within MIA there are limited gauges to measure delivered flows to the MI system.

4.3.2.1 *Fivebough and Tuckerbil Swamps*

Run-off from local catchments during June to November is conveyed in MI drainage channels. Structures within these channels control flow entering the swamps. Managed water can be supplied from the Murrumbidgee River using the MI supply system which connects to the drainage channels via constructed escapes.

The main sources of water to Tuckerbil Swamp are:

- rainfall
- stormwater run-off from the surrounding catchment
- some irrigation run-off from cropping and watering of pasture at the northern end
- drainage water when the contour drain overflows following heavy rainfall
- deliberate releases of 'excess' drainage water which can spill into the swamp at these points via automatic overflow structures (Fivebough & Tuckerbil WMT 2002).

MI can also deliver water on request from supply channels via escapes into drainage channels. The rate of delivery is not known.

There is no gauge at Tuckerbil or Fivebough Swamps. During the last watering event in 2010, OEH contracted NSW Office of Water hydrographers to undertake a number of flow gaugings. Flows of approximately 15 ML/d were typical of that filling event.

4.3.2.2 *Barren Box Swamp*

Water supply for Barren Box Swamp includes drainage water from the MIA, upper Mirrool Creek catchment flows, or water delivered from the Murrumbidgee River. Water is diverted into Barren Box Swamp from Willow Dam on Mirrool Creek.

Barren Box Swamp is filled between October to December to meet irrigation demand. Generally, by February, the storage volume is more accessible in the Active Cell and could be used for redistribution of flow to the Lower Mirrool Creek Floodplain. The Active Cell is considered more beneficial to use for supply to the Lower Mirrool Floodplain as water can be delivered by gravity. The Intermediate Cell incurs less evaporative losses, but it requires pumping for delivery.

There are gauges between the Intermediate and Active Cells in the wetland, and at the Mirrool Creek Floodway offtake. MI currently measure flows into and out of Barren Box Swamp, and other distributor networks.

Any use of Barren Box Swamp for interim storage of water destined for delivery to the Lower Mirool Creek Floodplain will require assessment of the risk of spreading alligator weed. This is a potentially significant constraint and is discussed further in Section 4.4.4 and Chapter 6.

4.3.3 Water accounting

Water supplied by SWC is generally measured at the user's diversion offtake and any transmission losses to deliver the water to the offtake are not accounted against the entitlement holder. This means there will be no transmission losses accounted against environmental water managers for water delivered to the bulk offtakes for the MIA (Main Canal and Sturt Canal). MI would assess transmission losses for water delivered to Fivebough Swamp, Tuckerbil Swamp and Barren Box Swamp and reduce the volume of water delivered to these assets accordingly.

4.3.4 Operational constraints and opportunities

During winter (June to July) parts of the MI water supply system may be closed for maintenance and upgrade works. Depending on the location of works, supply of water from the Murrumbidgee River may be restricted. MI can provide details of planned works, and likely limitations from these works to supply in the system.

4.4 Lower Mirrool Creek Floodplain

4.4.1 Water resource requirements

The Lower Mirrool Creek Floodplain is located west of Barren Box Swamp and has two geomorphic types of wetlands; the floodplain itself, and six discrete depressions that retain water. These are Narrabri, Highway, Belaley, Berangerine, Little Berangerine and Five Oaks wetlands. The floodplain is approximately 85 kilometres long, ranges in width from eight metres to four kilometres, and terminates at the Lachlan River. The floodplain is inundated by run-off from the local catchment, natural floods from Mirrool Creek or managed releases supplied from the Murrumbidgee River via the MI supply channels. The natural flow regime of the Mirrool Creek floodplain is largely ephemeral. Much of the floodplain is dominated by black box woodland, and hence requires watering every three to five years (for more information of the watering requirements of Black Box woodland refer to Appendix E).

Five end-of-system flows have occurred in the past century, with the last one occurring in 1989 (Mills 1998 cited Whitten & Bennett 1999).

There is currently no available data describing the volumes required to generate an end-of-system flow in the Lower Mirrool Creek Floodplain. Further investigation into the volumes required to inundate the whole system for wet and dry antecedent conditions is required.

4.4.2 Operating regimes

Mirrool Creek flows into Willow Dam upstream of Barren Box Swamp. From Willow Dam water can be sent into Barren Box Swamp or into the Wah Wah channel. Flow from the Wah Wah channel can be directed into the Lower Mirrool Creek Floodplain through a regulator. Water can also be supplied to the floodway directly from Barren Box Swamp. Fivebough Swamp is not inundated by flows in Mirrool Creek and relies on local run-off or managed flows. Tuckerbil Swamp can be watered via the Murrumbidgee Irrigation drainage network.

Supply of managed environmental water from the Murrumbidgee River to assets in the MIA is via the MI supply channels. Water is delivered into the MI system at Berembed Weir. The optimum time for delivery of managed events is either September/October (i.e. immediately prior to peak irrigation demand) or March/April (i.e. immediately after the peak irrigation demand). During this period the system is shut down for maintenance.

Water from Burrinjuck or Blowering Dam to Bundidgerry offtake takes approximately five days to deliver, however, MI orders are placed seven days in advance. Travel time from Bundidgerry offtake to Barren Box Swamp is approximately eight to nine days.

Within MIA there are limited gauges to measure delivered flows to the MI system.

Water supplies to inundate Mirrool Creek may be drawn from either Barren Box Swamp or the Murrumbidgee River. The active storage cell in Barren Box has a capacity 24,000 megalitres. A portion of this may be taken up by water reserved for irrigation of winter crops. Barren Box Swamp may be filled using irrigation drainage or water ordered from the Murrumbidgee River.

4.4.3 Water accounting

Water supplied by SWC is generally measured at the user's diversion offtake and any transmission losses to deliver the water to the offtake are not accounted against the entitlement holder. This means there will be no transmission losses accounted against environmental water managers for water delivered to the bulk offtakes for the MIA (Main Canal and Sturt Canal). MI will assess transmission losses for water delivered to the Lower Mirrool Creek Floodplain, and reduce the volume of water delivered accordingly. If environmental water is temporarily stored in Barren Box Swamp, then any evaporative losses incurred would be accounted against the environmental water manager but these would be relatively small. Any return flows (if suitably measured in drainage channels) will be credited to the user. However, the likelihood of any return flows occurring from environmental watering of Mirrool Creek is dependent on the magnitude of flows delivered. In particular, there are not expected to be any return flows if the goal is to water the Lower Mirrool Creek Floodplain only.

4.4.4 Operational constraints and opportunities

An issue that needs to be carefully managed is the presence of alligator weed (*Alternanthera philoxeroides)*, which does not occur in the Lachlan Valley. Measures to control the transport of alligator weed will need to be implemented prior to any environmental watering. The Department of Primary Industries (DPI) has indicated that it has developed suitable weed control measures, but these require approximately three months to prepare and implement. Therefore, it will be necessary to coordinate with DPI and ensure satisfactory implementation of weed control measures prior to any environmental watering and a risk assessment would still be required. It may also be necessary to coordinate with other authorities such as local councils and catchment-management authorities, as well as local landholders. In relation to local landholders, sufficient warning prior to an environmental flow in the Lower Mirrool Creek Floodplain will avoid potential damage to landholder infrastructure, crops and livestock.

4.5 Yanco Creek System

4.5.1 Water resource requirements

The bulk of water entering the Yanco Creek system is currently supplied by the Yanco offtake, which is situated on the Yanco Weir pool on the Murrumbidgee River. The Yanco Weir was completed in 1928, and in conjunction with Burrinjuck and Blowering Dams, facilitated an almost continuous supply of water into the Yanco Creek system for stock and domestic purposes (Glazebrook 2000).

From this structure, maximum in-stream bank flows (1,200 ML/d) are delivered over the majority of the year for irrigation purposes (Note: flows of 1,400 ML/d are being trialled during the 2011–12 irrigation year). Irrigation orders and supplementary flows are provided by outfall drains from the Coleambally Irrigation Area and numerous drains and escapes along the Billabong Creek from the associated Murray Irrigation District. Flows have been regulated from the offtake based on predicted flow requirements provided by SWC for the various sections of the system. Overbank flows, which provided replenishment to anabranches and wetlands in the system, regularly occurred throughout the system prior to 1994, but such events have become much rarer since 1997 as a result of drought.

Key wetland areas are Dry Lake and Molly's Lagoon (which is a combined system with the Gum Hole/Possum Creek Complex), Mundoora/Wilsons Anabranch, Wanganella Swamp, Forest Creek, Kerribirri Swamp, 'Rhyola' depressions and floodrunners, low-lying areas on 'Back Nullum' and Box Swamp on 'Blue Gate' (further detail on other assets in the Yanco Creek system are provided in Glazebrook 2000, Beal et al. 2004, Webster 2007).

There is currently limited information available on the volumetric requirements for several of the assets downstream of Wanganella Swamp. Where possible, information has been sourced on the natural flow regime, however, specific data identifying wetland volumes was not available at the time of reporting.

4.5.1.1 Dry Lake and Molly's Lagoon

Dry Lake is one of the most significant and largest wetlands on the Yanco Creek system. It fills via a channel off Yanco Creek when the Murrumbidgee River exceeds a height of 5.13 metres or 22,500 ML/d at Narrandera. The connecting channel (called Molly's Lagoon) also fills during periods of high operational flows in Yanco Creek in the high-allocation irrigation seasons. Molly's Lagoon is an Integrated Monitoring of Environmental Flows (IMEF) study site. Beal et al. (2004) reported that it has been over-watered.

Currently, Dry Lake holds water in an area of approximately 200 hectares. Historically, however, the surface area of the lake was possibly more than 400 hectares before a drainage line was cut into the south western end of the lake. This drainage line was most likely excavated in a bid to empty the lake earlier to allow for lake-bed cropping. The current owners are seeking to fill in the drain and manage the lake to maximise ecological benefit. Regulators were installed at Molly's Lagoon and Gum Hole Lagoon (completed March 2011) to better manage flows in the wetlands, and an operating plan is currently being developed (as at August 2011). Dry Lake is currently wet following the recent (spring to summer 2010) high flows. It last filled from environmental releases in 2000, retaining water for approximately six months.

4.5.1.2 Upper Yanco Creek Floodplain Wetland complexes

Several floodplain wetland complexes occur in upper Yanco Creek (e.g. Molly's Lagoon/Dry Lake Wetland Complex, Gum Hole/Possum Creek Wetland Complex, Washpan Creek, 'Chevrell Creek', 'Silver Pines', 'Arawidgee', 'Bundure' and 'the Frontage' wetland complexes). Webster (2007) identified 176 wetlands between the Yanco Creek offtake and Drainage Canal 800 (DC800) upstream of Yanco Bridge on the Kidman Way. Most wetlands in the area are sections of former river channels or anabranches (e.g. oxbows); small (less than two hectares); connected to a perennial stream at minimum regulated or natural flow levels; and dominated by grassy river red gum forest or black box woodland (Webster 2007).

These wetlands have been subjected to increased inundation periods due to the delivery of irrigation allocations, incurring 'loss' of regulated flows (Webster 2007). Webster's (2007) study aimed to inventory the upper Yanco Creek wetlands, identifying those larger than two hectares that are connected to Yanco Creek during regulated flows, for potential works to generate water savings. Many of the wetlands were found to be affected by grazing, weeds, and water logging, with two used for water storage.

The riparian zone in upper Yanco Creek is considered in relatively good condition compared to other riparian zones within the Murrumbidgee system (J Parrett 2011, pers. comm., 4 August).

4.5.1.3 Lake Urana

Lake Urana is a large shallow lake in a depression in the Riverine Plain filled intermittently by flood flows in Billabong, Coonong and Urangeline Creeks. In high flood events (such as in 1974) Billabong Creek can flood to the north and enter Lake Urana, which in turn spills into Lake Cocketgedong before it enters the Colombo Creek (Beal et al. 2004). The Lake fills every 10 to 20 years in large flood events and retains water for several years. The outer edges, however, (including the section in Lake Urana Nature Reserve) are flooded only for short periods. The reserve falls steeply to the lakebed on its eastern side but the rest of the reserve is gently sloping in a westerly direction (NSW National Parks and Wildlife Service 2001).

It is estimated that Lake Urana has a capacity of 250 gigalitres.

4.5.1.4 Mundoora/Wilson Anabranch complex

Mundoora/Wilson Anabranch is part of an anabranch complex which flows parallel, and to the north of, Yanco Creek. Mundoora Anabranch bifurcates from Yanco Creek 21.5 kilometres north-west of Jerilderie. Mundoora Anabranch is then renamed Wilson Anabranch approximately 7 kilometres downstream. The anabranch is sinuous and complex, supporting river red gum with a grassy understorey in the riparian zone.

Mundoora Anabranch is permanently flowing as it is in effect the Yanco Creek for this section, due to the rerouting of water around the two block banks. For Wilson Anabranch to flow, a recorded flow of 165 ML/d at Yanco Bridge gauge is needed. Inundation of Wilson Anabranch is slowed by in-stream vegetation growth (mostly cumbungi) (J Parrett 2011, pers. comm., 4 August).

4.5.1.5 Forest Creek

Prior to river regulation, the Forest Creek system would only have received water when the Murrumbidgee River was in flood, or when rainfall in the Billabong Creek catchment or local storms were sufficient to generate a flow of more than 1,500 ML/d at the Forest Creek offtake. This flooding regime would probably have created a series of small ephemeral wetlands along the creek system (White et al. 1985 cited in Beal et al. 2004). Black box occurs as a discontinuous fringe of riparian overstorey vegetation along Forest Creek, and is sometimes co-dominant with river cooba (*Acacia stenophylla*) (Glazebrook 2000). Cumbungi forms a narrow fringe along the littoral zone where the watercourse is well-defined, and dense stands where the channel is less defined and flow is slower (Glazebrook 2000).

The Forest Creek system is unregulated. Key wetland areas are Wanganella Swamp, and downstream wetlands such as Kerribirri Swamp, 'Rhyola' depressions and flood runners, break-out areas on 'Back Nullum', and Box Swamp on 'Blue Gate'. The Wanganella Swamp Management Plan (WSMP) describes the watering requirement for Wanganella Swamp.

On average during the period 1990 to 2000, properties below 'Back Nullum' received a flow in the Forest Creek from May/June until October/November, and relied on tanks in the creek to hold water as the creek dried up over summer. From 2000 onwards this regulated flow consisted of 100 ML/d until 2003–04, when it was changed to 80 ML/d in spring and summer, and 60 ML/d in winter and autumn. By 2008, flows in the system were reduced to zero. Until the 2010 floods, there had not been a flow in the Forest Creek Anabranch through 'Blue Gate' and 'Woorooma' since 1997. The lack of protocols for operation of the Forest Creek offtake regulator has compounded this problem in recent years, as winter/spring flushes were prevented from entering the creek system (Webster & Davidson 2010).

In 1994, following installation of the Forest Creek offtake regulator, a commitment was made to supply 100 ML/d over Warriston Weir, subject to remedial works being undertaken at McCrabb's regulator (at the downstream point of Wanganella Swamp), and in other parts of the system. The

Water for Rivers project stopped flows below Warriston Weir as a water saving measure in 2006, and it is now considered an unregulated system. The Forest Creek reach below Wanganella Swamp has returned to a more natural flow regime, with any flow being the result of excess inflow to Wanganella Swamp and local inflows.

4.5.1.6 Wanganella Swamp

The Wanganella Swamp system is located south of Wanganella township. It comprises the Eight Mile Creek, Wanganella Swamp and part of Clarkes Creek, all of which are hydrologically connected. The Wanganella Swamp system is a flow-through system, with Eight Mile Creek flowing under the Cobb Highway into Wanganella Swamp, and then into the Forest Creek Anabranch and on to properties further downstream. The swamp system is located on both freehold (55 per cent) and Crown land (45 per cent). Wanganella Swamp is a shallow, basin-shaped wetland with sandhills on its eastern margin. The Wanganella Swamp basin is approximately 470 hectares in size, and water spreads out across this depressional area before returning to the main creek channel. It should be noted that under natural conditions Wanganella Swamp would have been much smaller, with its increased size owing to human intervention in flow regimes in the system (J Parrett 2011, pers. comm., 15 August).

Recommendations in the Management Plan for Wanganella Swamp (Webster & Davidson 2010) intend for at least 25 per cent of all unregulated flows past Jerilderie (which would have entered Forest Creek prior to European development) continue to do so. This would ensure that at least some natural flood events will reach Wanganella Swamp and maintain the health of the riparian vegetation. Also, if predicted climate change results in a reduction in natural flood events, environmental water is to be delivered to Wanganella Swamp to maintain waterbird-breeding events which have been initiated as a result of natural flood events. The exact area flooded and the amount of water required to achieve this will depend on what the aim of each environmental flow is. If the aim is to fill the entire wetland (approximately 470 hectares) it will take approximately 1,500 megalitres, not taking into account transmission losses, evaporation, deep leakage or plant use (Webster & Davidson 2010). There are a number of possible water delivery mechanisms. More than 20,000 megalitres could be required if flows are to be delivered using Murray Irrigation Limited infrastructure via Billabong Creek (E Wilson 2011, pers. comm., 19 September).

The Draft Forest Creek Resource Management Plan (Glazebrook 2000) indicated that an environmental allocation of up to 4,000 megalitres at Warriston Weir is required between October and January (inclusive), one in every three to four years on average. This would provide an environmental flow in addition to the summer and winter target flows of 80 ML/d and 60 ML/d respectively, suggested by Beal et al. (2004).

Beal et al. (2004) also stipulated that unregulated and rain rejection flows should be permitted to pass through the Forest Creek system for environmental purposes, but noted this is operationally difficult to implement because of inadequate capacity of the Forest Creek offtake and the regulated section of Forest Creek.

4.5.1.7 Kerribirri Swamp

The natural topography through the Kerribirri property comprises low-lying country, flood runners, and a small creek (Kerribirri Creek) that flows out of Forest Anabranch to the south east. These areas total approximately 750 hectares. Installation of structures such as weirs during the 1930s, and more recently the impact of dense Cumbungi growth, has encouraged the movement of water into these low-lying areas and they now receive much more water than they would have naturally. Construction of a retaining bank and numerous block banks during the 1950s was designed to prevent water breaking out of the main creek and flooding low-lying country between the Forest Anabranch and Billabong Creek.

A large depression that is fed from Kerribirri Creek holds water all year, and provides water storage. A licensed block bank and pipe structure crosses this creek at the cottages further downstream and holds water between Kerribirri Creek offtake and the block bank.

While much of the water in low-lying areas dries up over summer, there are other deeper depressions, apart from the storages mentioned above, that remain permanently inundated (Beal et al. 2004)

Further assessments are required to determine the volumetric requirement of Kerribirri Swamp (Webster & Davidson 2010).

4.5.1.8 'Rhyola' depressions and floodrunners

'Rhyola' is a cattle grazing property. Low-lying areas on 'Rhyola' sustain extensive areas of dense lignum, with nitre goosefoot (*Chenopodium nitrariaceum)* on adjacent high ground. Annual grasses and roly poly (*Salsola kali*) comprise much of the groundcover. The main flood runner is fringed with black box, nitre goosefoot and juncus (*Juncus* spp.) in the understorey.

An area to the north of the Forest Anabranch on 'Rhyola' is a declared wildlife sanctuary, through an agreement between the landowner and the National Parks and Wildlife Service. The area was originally declared to protect waterbirds (Beal et al. 2004).

Further assessments are required to determine the volumetric requirement of wetlands and floodrunners on 'Rhyola' (Webster & Davidson 2010).

4.5.1.9 'Back Nullum' low-lying areas

Several hundred hectares of low-lying country to the south of the Forest Creek Anabranch flood when there are good winter/spring flows in the creek. There are no restrictions to flow, and the area generally floods each year from about May, and remains inundated for five to six months. The depth of water in an average season is approximately 50 centimetres, and up to 1 metre in the deepest sections (Glazebrook 2000).

Further assessments are required to determine the volumetric requirement of 'Back Nullum' low-lying areas (Webster & Davidson 2010).

4.5.1.10 Box Swamp on 'Blue Gate'

Box Swamp is a horseshoe-shaped depression of approximately 100 hectares. The Forest Creek Anabranch flows through one side of the swamp, and there are no restrictions to flow. This area usually floods from approximately August until the Forest Creek Anabranch ceases to flow (generally January, depending on summer rain). The swamp currently only receives water during moderate-to-large floods. When flooded, the maximum depth of water is approximately 1.5 metres (Glazebrook 2000).

Further assessments are required to determine the volumetric requirement of Box Swamp and floodrunners on 'Rhyola' (Webster & Davidson 2010).

4.5.2 Operating regimes

Supply of water to the Yanco Creek system is dependent on several factors, including variability of inflows into the upper reaches of the two major irrigation storages (Blowering and Burrinjuck) and the Upper Billabong Creek catchment, the capacity of in-stream infrastructure such as weirs and channels to distribute the water, and the extent of physical flow impediments. These in-stream impediments include private and public weirs, siltation slugs, large woody debris, cumbungi and willows. Water is also known to escape into floodrunners, anabranches and oxbows at different flow levels.

In times of high flow demand in the Yanco Creek system, up to 1,400 ML/d can be directed into the system, but considerable flooding occurs at several points in local areas. Under existing regulated flow conditions, a minimum diversion of 500 ML/d at the Yanco Creek offtake is provided for stock and domestic requirements in the Yanco Creek system year round. Extra diversions are made in summer and autumn for irrigation.

Supplementation of flows from Murray Irrigation Limited and the Coleambally Irrigation Area has become critical to the overall operation of the Yanco/Billabong Creek system. Finley Escape (off the Mulwala Canal) is used during the irrigation season to supplement flows in Billabong Creek, below Jerilderie and Forest Creek, with water from the Murray Valley (Glazebrook 2000). Wollami Escape is also used to supplement flows directly into Forest Creek.

Until 2007, SWC provided 26.2 GL/yr (reduced from 36.5 GL/yr in 2003–2004 as a result of changes to the delivery method of the flows) of replenishment flow as basic landholder rights for stock and domestic diversions downstream of Warriston Weir. Following additional water savings, these replenishment flows which indirectly contributed to the watering of some wetlands in the system were discontinued.

Travel time for regulated flows in the system must also be considered in conjunction with losses when making releases to meet environmental objectives. As shown in Table 9, it takes approximately five to six weeks for regulated flows to pass from the Murrumbidgee irrigation dams (Blowering and Burrinjuck) through the Yanco Creek system to Moulamein (Beal et al. 2004).

Table 9: Travel times for flows in the Yanco Creek system. (Source: Beal et al. 2004)

Reach	Travel time (days)	Cumulative (days)
Dams to Yanco Offtake	7–8	7–8
Yanco Offtake to Tarabah Weir	2–3	10
Morundah to DC800 (Yanco)	7	17
DC800 to Puckawidgee (Yanco)	7	24
Tarabah to Innes Bridge (Colombo Creek)	8	31
Innes Bridge to Jerilderie (Billabong)	2	33
Jerilderie to Hartwood Weir	4	37
Hartwood to Conargo	1–2	38
Conargo to Darlot	7	45
Darlot to Moulamein	7–10	55
Forest Creek Offtake to Warriston Weir	5–6	61

Coleambally Irrigation can deliver water to the Yanco Creek system at three locations:

- Coleambally Catchment Drain (CCD) delivers to the upper reaches of Yanco Creek. Its capacity is 150 to 200 ML/d.
- DC800 delivers to Yanco Creek where the Kidman Way bisects the creek. Its capacity is 50 ML/d.
- Western Coleambally Channel (WCC) delivers to Billabong Creek downstream of Wanganella Swamp. This channel is 180 kilometres, and has a capacity of 150 ML/d subject to irrigation use. (WCC is Coleambally Creek in the upper reaches, then Eurolie Creek in the lower reaches.) (A Evans (CICL) 2011, pers. comm., 25 August).

The Coleambally Irrigation delivery network and the locations of CCD, DC800 and WCC are depicted in Figure 10.

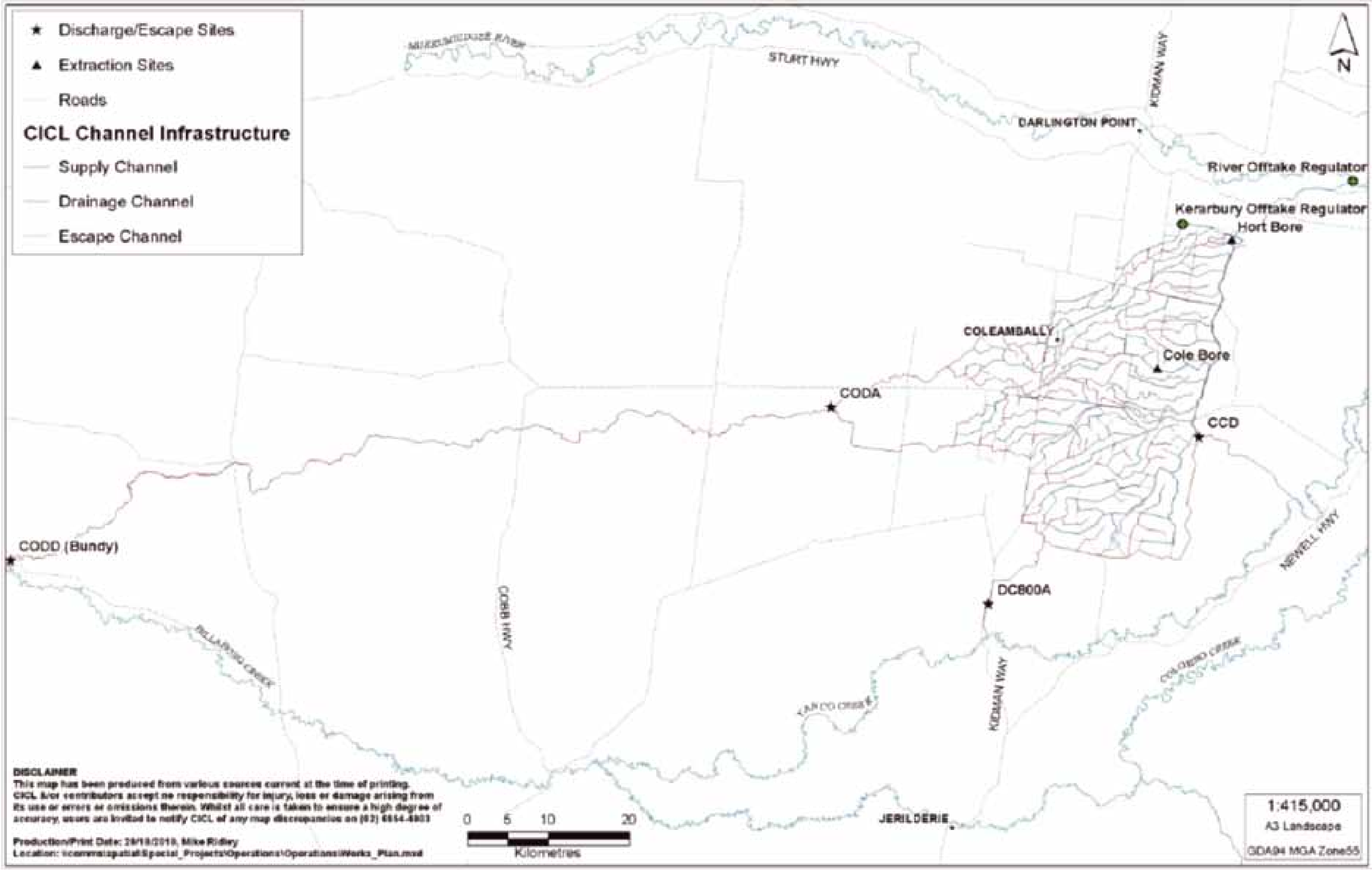


Figure 10: Coleambally Irrigation supply network. Note, WCC is marked on the figure as COD (Coleambally Outfall Drain). (Source: Coleambally Irrigation 2010)

4.5.2.1 Dry Lake and Molly's Lagoon

Dry Lake supports river red gums and receives inflows only in periods of high unregulated flows in the Murrumbidgee River. A flow rate of 23,000 ML/d at Narrandera is reported as the trigger flow rate (Murray 2008). While such events occurred regularly in years prior to 1997 for an average duration of 15 days, a 13-year dry period, interrupted by a brief event in 2000, was experienced until the 2010 floods.

Works to install a wetland regulator to exclude regulated flows but maximise environmental flow delivery rates was completed in June 2011 (J Maguire (OEH) 2011, pers. comm., 9 August). The regulator will be used to reintroduce a more natural inundation regime in the wetland, and for water savings.

4.5.2.2 Mundoora/Wilson Anabranch complex

Mundoora and Wilson Anabranches are part of an anabranch complex which flows parallel, and to the north of, Yanco Creek. Mundoora Anabranch bifurcates from Yanco Creek 21.5 kilometres north-west of Jerilderie. Mundoora Anabranch has a series of block banks on it, with outlets at Nine Mile and McCaughley Dams on Yanco Creek. These dams on Yanco Creek effectively block flows in the creek, making the anabranch complex the main channel for flows (J Parrett 2011, pers. comm.). Water in the anabranch flows through a brick weir, forming a series of wetlands and a narrow channel.

Mundoora Anabranch forms a horseshoe lagoon downstream of Wilson Anabranch Offtake. This enables water to back up into Wilson Anabranch and the Yanco Creek proper. Wilson Anabranch Offtake is approximately 7 kilometres downstream of the bifurcation from Yanco Creek, where a 600-millimetre pipe enters Wilson Anabranch. Wilson Anabranch is braided in its upper reaches but is formed into a human-made wetland downstream. There are two irrigation licences on Wilson Anabranch. Both of these licences are currently being converted to the Yanco Creek proper.

Due to the re-routing of water around block banks the Mundoora Anabranch is constantly flowing, and effectively operates as the main channel of Yanco Creek at this point. Flows of 165 ML/d at Yanco Bridge will cause Wilson Anabranch to commence-to-flow (J Parrett 2011, pers. comm.).

4.5.2.3 Forest Creek

The Forest Creek system receives water from several different sources:

1) Colombo Creek, which receives regulated and unregulated flows from the Murrumbidgee River via Yanco Creek.

2) Billabong Creek, which carries unregulated flows from the Upper Billabong Creek catchment, and regulated and unregulated flows from the Murrumbidgee catchment from the Murrumbidgee River via the Yanco and Colombo Creeks.

3) Finley Escape (off Mulwala Canal). Since the 1994–1995 irrigation season this escape has been used to carry water from the Murray River catchment to supplement flows in Billabong Creek below Jerilderie and Forest Creek during summer (up to 250 ML/d) (Nias 2005).

4) Wollami Escape and Blighty No. 17, which both discharge directly into Forest Creek.

Prior to river regulation, the Forest Creek system would only have received water when the Murrumbidgee River was in flood, or when rainfall in the Billabong Creek catchment or local storms were sufficient to generate a flow of more than 1,500 ML/d at the Forest Creek offtake (Glazebrook 2000 cited in Webster & Davidson 2010).

Current estimates suggest that with Hartwood Weir boarded up, Forest Creek will commence to flow when there is a flow in excess of 100 ML/d in Billabong Creek. If the boards in the Weir were removed there would need to be a flow in excess of 500 ML/d (J Parrett 2011, pers. comm., 15 August). This is because the reduced level of the Forest Creek offtake is about 2 metres above the bed of Billabong Creek (White et al. 1985 cited in Webster & Davidson 2010).

4.5.2.4 Wanganella Swamp

Without intervention the watering regime at Wanganella Swamp is ephemeral, relying on flood flows in the Murrumbidgee River and Billabong Creek to enter the Forest Creek system (via Hartwood Weir and the Forest Creek offtake regulator), and then the swamp. This scenario was modelled by OEH, with the following potential decision triggers:

- a maximum daily diversion of 300 ML/d to Forest Creek at Hartwood Weir when flows over Hartwood weir equal or exceed 1,500 ML/d—using this option results in an unknown final volume being delivered to the swamp and significant transmission losses
- no uncontrolled diversions to enter Forest Creek when flows into Hartwood Weir are less than 1,200 ML/d
- uncontrolled flows commence into Forest Creek when Hartwood Weir inflows equal 1,200 ML/d.

An efficient alternative water-delivery regime is to establish an environmental flow to be used during extended dry periods to maintain wetland health. To minimise losses, this water would be supplied from the nearby Billabong Creek, whose flows would be increased by delivering water from the Murray Irrigation Limited system via the Finley Escape, which has a capacity of 250 ML/d. The Finley Escape enters Billabong Creek approximately 30 kilometres upstream of Hartwood Weir, delivering flows to Forest Creek at the Hartwood Weir pool when the pool is at or near spilling level (this provides sufficient head for Forest Creek to commence to flow). Flows in Forest Creek enter Wanganella Swamp 50 kilometres downstream of the Forest Creek Offtake. There are also three smaller Murray Irrigation Limited escapes with capacity to deliver flows directly into Forest Creek upstream of Wanganella Swamp. These have a combined capacity of 50 to 60 ML/d.

4.5.2.5 Downstream wetlands

Downstream of Wanganella Swamp, Forest Creek becomes Forest Creek Anabranch, flowing approximately parallel to (and south of) Billabong Creek, to Moulamein. Major wetlands downstream of Wanganella Swamp (e.g. Kerribirri Swamp and 'Rhyola' wetlands and floodrunners) receive inflows from Forest Creek Anabranch.

The Wanganella Swamp Management Plan (WSMP) notes that water can be supplied downstream of the swamp by allowing through-flow. It is a proposed action of the WSMP to investigate the options for maintaining environmental health of Forest Creek Anabranch and downstream wetlands once the plan is implemented. On average during the period 1990 to 2000, properties below 'Back Nullum' received a flow in Forest Anabranch from May/June until October/November, and relied on tanks in the creek to hold water as the creek dried up over summer. Until the 2010 floods, there had not been a flow in the Forest Creek Anabranch through 'Blue Gate' and 'Woorooma' since 1997. The lack of protocols for operation of the Forest Creek offtake regulator has compounded this problem in recent years, as winter/spring flushes were prevented from entering the creek system (Webster & Davidson 2010).

Webster and Davidson (2010) highlight the requirement for detailed assessment of these wetlands to determine what works and water requirements are needed.

4.5.2.6 Existing and proposed water delivery infrastructure

The Yanco Creek System has been identified to contain 36 regulating structures (Molino Stewart Report 1999 cited in Beal et al. 2004). Many of these weirs are in various states of repair and require refurbishment or removal to improve flow throughout the system. SWC conducted a review of the Yanco Creek system weirs in 2007 and identified a number of weirs that require removal and/or maintenance. Removal and modification of these would contribute to maximising potential ecological benefits from environmental flows.

Further investigations have been conducted to determine the feasibility of creating alternative supply channels away from the Yanco Creek system at strategic locations to enable greater capacity for larger volumes of water, and enhance habitat conditions within the creek system (Beal et al. 2004). SWC and DPI have been conducting preliminary investigations on a range of engineering options to improve supply and reduce the impact of regulated streams on natural ecosystems.

The Yanco Creek system Natural Resource Management Plan also identified that the McCrabb's regulator and spillway should be modified to accommodate 100 ML/d plus flows, and de-silting is required upstream of the regulator to facilitate the passage of flows (Beal et al. 2004). Modifications to the McCrabb's regulator will enable better management of water supplied to Waganella Swamp and help to prevent flooding of the Cobb Highway at Wanganella.

4.5.2.7 Water accounting

Water supplied by SWC is generally measured at the user's diversion offtake and any transmission losses to deliver the water to the offtake are not accounted against the water share holder. For potential deliveries to wetlands and anabranches on the regulated Yanco Creek system this means there will be no transmission losses accounted against environmental water accounts for water delivered to the specified outflow points on the creeks. However, losses related to delivery to assets in the unregulated portion of the system (below Warriston Weir) would likely need to be accounted for by the environmental water manager.

Diversion of any flow release from Warriston Weir other than for environmental water deliveries is not anticipated, as all the landholders on that region are now supplied via pipes for their stock and domestic supplies. Further investigation is required for the regulated stretches of Yanco Creek system although the risk of another regulated user diverting water ordered by the environmental water manager is considered to be small.

Section 47 of the Murrumbidgee Water Sharing Plan 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 yet been formally established.

4.5.3 Operational constraints and opportunities

Maximum in-stream bank flows (1,200 ML/d) are delivered over the majority of the year for irrigation purposes. Higher diversion volumes can be managed, however this tends to cause flooding and increased system losses. Flow rates need to be monitored closely in Washpan Creek where it leaves Yanco Creek and flows over Spillers Regulator before returning to Yanco Creek downstream of Tarabah Weir in Morundah.

There are a number of locations along the Yanco Creek-to-Morundah section where restrictions occur and inhibit the supply and delivery of water. These restrictions are commonly known as in-stream impediments.

Flooding of private property can occur when the bank-full capacity of Colombo Creek exceeds 600 to 650 ML/d. Despite de-snagging works in 1992 that achieved a 15 per cent increase in capacity along this section of Colombo Creek, further removal of strategic obstructions may be considered.

There are also freshwater catfish (*Tandanus tandanus*) in the Yanco Creek system, mainly in Colombo Creek (J Maguire (OEH) 2011, pers. comm., 9 August). Freshwater catfish have experienced a significant decline in abundance and distribution throughout the species' southern range, resulting in it being listed as 'threatened' in Victoria and 'protected' in South Australia (McCarthy et al. 2007). The species is listed as declining by Lintermans (2007). Freshwater catfish require still or slow-flowing water and habitat with aquatic vegetation. They are predominantly benthic feeders and do not migrate, preferring to remain in the same area for most of their lives. Spawning is cued by changes in water temperature rather than water level. Because they are largely sedentary and don't respond to changing water levels, they are considered at risk under low and cease-to-flow conditions.

There are existing flow impediments (e.g. abundant Cumbungi within the Forest Creek channel, Peppinella Weir and Junction Weir) which mean that minor natural flows are unlikely to reach Wanganella Swamp and downstream wetlands.

Other supply sources, such as escapes and drainage channels, also have supply limitations. Table 10 depicts creek flow impediments and system losses within the Yanco Creek system (Beal et al. 2004). This information is offered as a guide to potential losses incurred in delivering environmental water to the Yanco Creek system.

Table 10: Creek flow impediments and system losses in the Yanco Creek system. (Source: Beal et al. 2004)

	Offtake to Morundah	Morundah to DC 800	DC 800 to Puckawidgee	Conargo to Wanganella	Wanganella to Darlot	Columbo Creek	Junction to Jerilderie	Jerilderie to Algudgerie^	Algudgerie to Hartwood	Forest Creek	Hartwood to Conargo	Darlot to Moulamein	Totals
Length of Reach	44 km	108 km	106 km	68 km	64 km	148 km	46 km	28 km	61 km	27 km	20 km	79 km	799 km
Total No. Of Willows	350	>600	>500	>180	>30	>720	>400	>320	100	>220	>75	>15	>3,510
Total No. Large Woody Debris	>500	>600	>4,240	>150	>135	>1,850	>760	>600	>450	>120	>200	>105	>12,980
Total No. Floodrunners and Ox Bows	9	7	7	8	1	11	2	4	5	3	8	1	66
Total No. Wetlands	2				2							1	5
Total No. Cumbungi and weed Infestations	2	11	13	5	2	5	8	8	4	14	3		75
Weirs (state)	2					3	1	1	1	2			10
Weirs (private)		1	4	7	1	5			4	3		1	26
Losses Average ML/d	**Offtake to Morundah**	**Morundah to Darlot**				**Columbo to Conargo**						**Darlot to Moulamein**	
1998–99	16.5	16.8				39.2							
1999–00	35.4	63.7				25.6							
2000–01	48.0	38.7				23.9							
Losses Average ML/d	**Offtake to Morundah**	**Morundah to DC 800**	**DC 800 to Puckawidgee**	**Puckawidgee to Darlot**		**Columbo Creek**	**Junction to Jerilderie**	**Jerilderie to Columbo**				**Darlot to Moulamein**	
2001–02	89.2	27.3	105.3	109.5		61.8	35.5	29.1					
2002–03	57.3	41.7	52.0	57.5		59.7	26.9	38.8					

* *Note: Losses calculated as averages over the season*

4.6 Lowbidgee Floodplain

4.6.1 Water resource requirements

The Lowbidgee wetland complex includes three distinct areas: the Nimmie-Caira system, the Fiddlers-Uara Creek system, and the Redbank system, which can be further subdivided into North Redbank and Yanga. Each system is characterised by different topography, flooding behaviour and ecological communities. The Nimmie-Caira system is characterised by extensive areas of lignum, Redbank is predominantly river red gum forests and woodlands, and the Fiddlers-Uara system (which has the least frequent watering), is characterised by lignum and sparse black box woodland.

Under natural conditions floodplain inundation occurred on average every two to three years in some portions of the Lowbidgee, although higher areas were flooded at intervals of five to 10 years. Flood events tended to `cluster', whereby the system would experience two or three floods in quick succession followed by a drier period (Eastburn 2003).

Until recently the entire Lowbidgee (with the exception of Murrumbidgee Valley Nature Reserve) was privately owned, but in 2005 a property occupying Yanga was purchased by the then NSW Department of Environment and Conservation. It is now managed as Yanga National Park (also known as Murrumbidgee Valley National Park). Historically, landholders have opportunistically cropped the Nimmie-Caira section and harvested river red gums from North Redbank and Yanga. Over the past 20 to 30 years, landholders and SWC have installed an increasing number of regulators, channels and block banks to allow them to control inundation. Under natural conditions the Lowbidgee was inundated only during high flow events that were sufficiently large enough to overtop the riverbanks. However, controlled releases can now be made which allow environmental managers to take advantage of small environmental allocations. For instance, in recent years relatively small volumes have been used to water selected small wetlands within Yanga National Park and the Nimmie-Caira system that are known to be breeding sites for southern bell frogs and to water priority river red gum forests.

The Lowbidgee is not included in the Murrumbidgee Regulated River Water Sharing Plan however the plan is being amended to include the Lowbidgee. The current plan includes provision for the diversion of supplementary flows (known as Lowbidgee Access flows) into the Lowbidgee. Supplementary flows are generally derived from tributaries that enter downstream of Burrinjuck and Blowering Dams, but also from dam spills which cannot be regulated. SWC operates the regulators that divert flows into the Lowbidgee (as well as some internal regulators) when such events occur, in conjunction with landholders. Under current arrangements water is shared equally between the Nimmie-Caira and Redbank systems. Water is then shared equally between North Redbank and Yanga.

Modelled results using the Integrated Quantity and Quality Model (IQQM) shows the average annual diversion of Lowbidgee Access water into the Lowbidgee will be approximately 300,000 megalitres under current management arrangements, however, annual diversions vary considerably.

The location of key assets in the Lowbidgee is depicted in Figure 11.

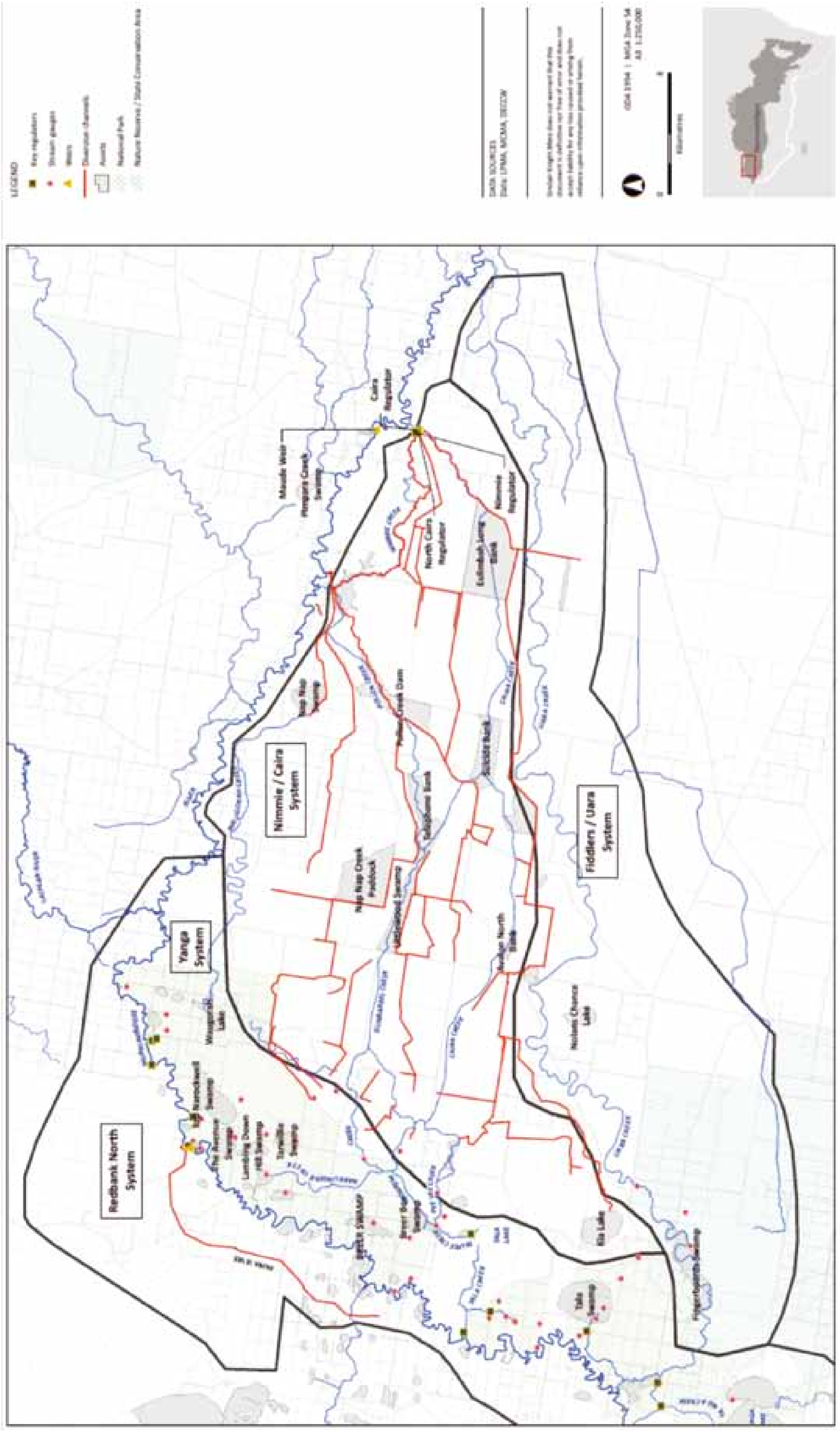


Figure 11: The location of key assets in the Lowbidgee.

4.6.1.1 Nimmie-Caira

The Nimmie-Caira system comprises a series of interconnected channels which flow from east to west. Flows enter this system through regulators located near Maude, or via overbank flows in larger flood events, and moves westward towards Tala Lake on the southern Redbank floodplain. Since the 1980s an extensive channel network with bays and regulators has been built to manage internal flows and allow efficient delivery of water to specific targets including stock and domestic, environmental and agricultural assets. Diversions into the system are highly controlled and volumes reaching floodways and rookeries are determined by landholder management decisions.

Environmental watering within the Nimmie-Caira floodplain is a complex function of agreed floodway watering rules, drainage flows and discretionary diversions into rookeries and swamps (either by the Nimmie-Caira League or individual landowners). The success of bird breeding is often tied to cropping bay watering, as these areas provide food for some nesting birds. Hence, the distinction between agricultural and environmental water use in Nimmie-Caira is unclear as the environment gains some advantages from certain agricultural water use and vice versa. Key environmental assets and the volumes required to fill them are provided in Table 11.

Table 11: Key water management areas and their associated water demands. (Source: SKM 2008)

Wetland	Area (Ha)	Volume to Fill (ML)
Eulimbah Long Bank	600 to 1,200	6,930
Suicide Bank	500	3,465
Avalon Swamp	50 to 70	552
Nap Nap Swamp	100 to 750	1,125
Pollen Creek Dam	100	1,155
Avalon North Bank	500	5,775
Littlewood Swamp	200	2,310
Telephone Bank	1,000	11,550
Pollen Creek	1,000	11,250
Nap Nap Creek Paddock	500	5,625
Talpee Creek/Pee Vee Creek	600	6,630
Nolans Chance (Loorica) Lake*	150	1,657
TOTAL		**58,025**

** This asset is within the Fiddlers-Uara Creek system but can be watered from Caira Creek via Avalon Swamp.*

In addition to these volumes there may be transmission losses associated with wetting of the supply channels. Transmission losses vary depending on antecedent conditions (elapsed time since rainfall and/or previous flow event) for assets at the western end of the system. A number of these wetlands are key breeding sites for the southern bell frog, and all support bird breeding events as well as a variety of aquatic and riparian vegetation communities. Watering objectives for Nimmie-Caira include supporting:

- southern bell frog breeding at key sites
- bird breeding events when there is sufficient water
- aquatic and riparian vegetation communities.

IQQM modelling indicates that the average annual diversion of Lowbidgee Access water into Nimmie-Caira will be approximately 150,000 megalitres. While this water is managed by SWC and owned by landholders, under current management practices this will be sufficient to meet environmental water needs most years. However, during dry years there may be minimal water from Lowbidgee Access entitlements. The focus is therefore to provide environmental water in dry years to support the bird and frog breeding events, and their habitats.

4.6.1.2 Yanga System

Yanga lies to the west of the Nimmie-Caira and Fiddlers-Uara systems and borders the Murrumbidgee River. Extensive river red gum forest is the dominant vegetation community. These forests are occupied by scattered wetlands that rely on overbank flows for filling (Kingsford & Thomas 2001). These include Piggery, Breer and Tarwillie Swamps, and Yanga Lake, which are filled intermittently by floodplain flows. Yanga is connected to the Nimmie-Caira system by a number of creeks which are also connected to Tala Lake (in the middle of the Yanga system).

Natural inundation of Yanga occurs when Murrumbidgee river flows in the vicinity of Redbank Weir exceed 9,000 ML/d (J Maguire (OEH) 2011, pers. comm., 28 October). Redbank Weir was constructed to permit controlled inundation in response to concerns regarding the reduction in floodplain watering arising from river regulation. There has been a significant reduction in the occurrence of high flow events large enough to spill into the Yanga system. Most flows therefore are in the form of diversions, which are permitted only when natural flood events in the upper Murrumbidgee River produce flows that could not be captured by upstream storages, or when environmental water is available. Water is delivered to Yanga through the Yanga and Waugorah regulators. These control the rate and progression of inundation throughout the area. Return flows from the Tala area to Tala Creek occur via the Tala Escape.

Historically, flow diversions into Yanga have not been gauged, however in 2009 OEH installed a number of flow-gauging stations. The additional gauges will provide the following information:

- flow from the Nimmie-Caira system into Tala Lake
- flow through the Woolshed Creek, Yanga and Waugorah Regulators
- water levels in Tarwillie, Narkungerie, Breers, Top Narrockwell, the Avenue (Two Bridges) Swamps, and Piggery Lakes to allow the recoding of wetland persistence and wetting-drying cycles.

The volumes required to water selected areas in Yanga are provided in Table 12. A flow of at least 160,000 megalitres is required to inundate the entire Yanga floodplain (including Yanga Lake).

IQQM modelling indicates that the average annual diversion of Lowbidgee Access water into Yanga will be approximately 75,000 ML (i.e. 25 per cent of 300,000 ML). This water is controlled by OEH and is expected to be sufficient to meet environmental water needs. However, in dry years there will be little or no water from Lowbidgee Access entitlements. The focus is therefore to provide environmental water to:

- support annual watering of key southern bell frog breeding sites
- support watering of priority river red gum forest and woodland
- support bird breeding events when water availability is sufficient
- water remaining river red gum communities as permitted by water availability.

Table 12: Volumes required to inundate selected assets in Yanga.

Asset	Water supplied via Redbank system#			Water supplied via Maude system^	
	Volume to get water to asset (ML)	Volume before water flows out of asset area (ML)	Volume retained (ML)	Volume to get water to asset	Volume before water flows out of asset area
Yanga	n/a	3,200	3,200	n/a	n/a
McCabes Gap	1,400	2,800	1,400	n/a	n/a
Top Narockwell	1,400	3,900	2,500	n/a	n/a
Tarwille	8,500	11,500	3,000	n/a	n/a
Piggery Lakes	5,700	16,000	10,300	n/a	n/a
Narkungerie Swamp	16,000	20,000	4,000	n/a	n/a
Breer Swamp	20,000	25,000	5,000	n/a	n/a
Shaws Swamp	n/a	500	500	n/a	n/a
Tala Lake	35,000	52,000	17,000	1,500–30,000*	n/a
Tala Swamp	63,000	66,500	3,500	34,000	n/a
Yanga Lake	100,000	165,000	65,000	52,000	117,000

** - This varies according to whether the irrigation channels used to deliver water have been wetted already by irrigation flows. If the channels are dry prior to delivery of environmental water, more water is required to reach the target asset because much of it is absorbed by the channel.*

#Supplied from channels off Redbank Weir.

^Supplied from channels off Maude Weir.

4.6.1.3 North Redbank

The North Redbank system contains a number of wetland complexes including Paul Coates Swamp, the Paika Creek/Paika Lake complex, the Tori/Lake Marimley/Jindeena complex, and the Paika/Narwie/Wynburn complex. Most wetlands of the North Redbank system are located on private land and dominated by river red gum communities. Prior to flooding in December 2010, parts of the system had not been watered for up to 10 years.

Under natural conditions North Redbank was watered by overbank flows. Diffuse natural creek lines run across the floodplain, spreading floodwater into depressions and swamps. The only well-defined channel is the North Redbank Channel.

IQQM modelling indicates that the average annual diversion of Lowbidgee Access water into North Redbank will be approximately 75,000 ML. This water is controlled by OEH and is expected to meet environmental water needs. However, in dry years there will be little or no water from Lowbidgee Access entitlements.

4.6.1.4 Fiddlers-Uara

This creek system runs in a south-westerly direction, along the southern edge of the Nimmie-Caira system. It is fed by large overbank flood events which break out of the Murrumbidgee River between Hay and Maude, providing water to the southern section of the lower Murrumbidgee floodplain and to natural depressions located to the south east of Balranald. Historically, it is the least watered section of the Lowbidgee wetland complex, with relatively high offtakes that were once channels of ancestral streams. This area is above the influence of the Maude Weir pool and relies on rare large natural floods for inundation.

The Uara Creek channel passes close to the southern edge of Caira Creek, and in large events spills may pass from South Caira Channel into the Uara system and vice versa, and also into Yanga. South Caira Channel flows can be diverted through private irrigation channels into Uara Creek and Yanga Lake. In 2010, approximately 15,000 ML was diverted into the lower section of Fiddlers Creek from the South Caira Channel at the Warwaegae offtake regulator. Flows continued down the creek system into the Murrumbidgee Valley Nature Reserve.

Historically, the natural floodplain of this creek system was considerably larger, however woodland and other significant vegetation areas in the system are now degraded, or stressed, due to the greatly increased intervals between periods of inundation.

4.6.2 Operating regimes

4.6.2.1 Nimmie-Caira

The Nimmie-Caira system includes two main (natural) channels, namely Caira Creek and Nimmie/Pollen Creek (Figure 12). Caira Creek runs through the southern half of the Nimmie-Caira system with Nimmie/Pollen Creek to the north. North Caira Channel has been constructed between the two natural creek systems. Regulated flow enters the Nimmie-Caira system from the Maude weir pool through these three channels, each of which has a separate regulator. Overflows occur when Murrumbidgee River flows exceed 20,000 ML/d. Limited data is available to quantify the volume of overbank flows that enter the system.

Caira Creek has a flow capacity of 800 ML/d. North Caira Channel was designed with a capacity of 1,000 ML/d, but its practical capacity is 800 ML/d. The capacity of Nimmie Creek is not known but the offtake to Nimmie Creek has a rated capacity of 3,000 ML/d.

The eastern end of the Caira Creek system is separated from the Fiddlers-Uara Creek system by a ridge of high ground running along its southern edge, although to the west of Warwaegae Road, flows can move between the two systems. Historically, a large proportion of floodwater in Caira Creek flowed into the northern Pollen Creek system upstream of Warwaegae Road. Floodplain development has restricted this somewhat, however it is still likely to be a key flow route in larger events. Under current conditions, most of the Caira Creek floodwater continues westwards into Talpee Creek and Tala Lake at the eastern side of the Yanga system. Movement of water from Caira Creek to Tala Lake depends on water levels in the lake, and whether large overbank flows have occurred within Redbank.

Nimmie Creek is joined by the Sandy Creek runner (fed by overflows), approximately 10 kilometres downstream of the offtake from the Murrumbidgee River to form Pollen Creek, before turning westwards to join the Monkem and Talpee Creeks at the eastern edge of the Redbank system.

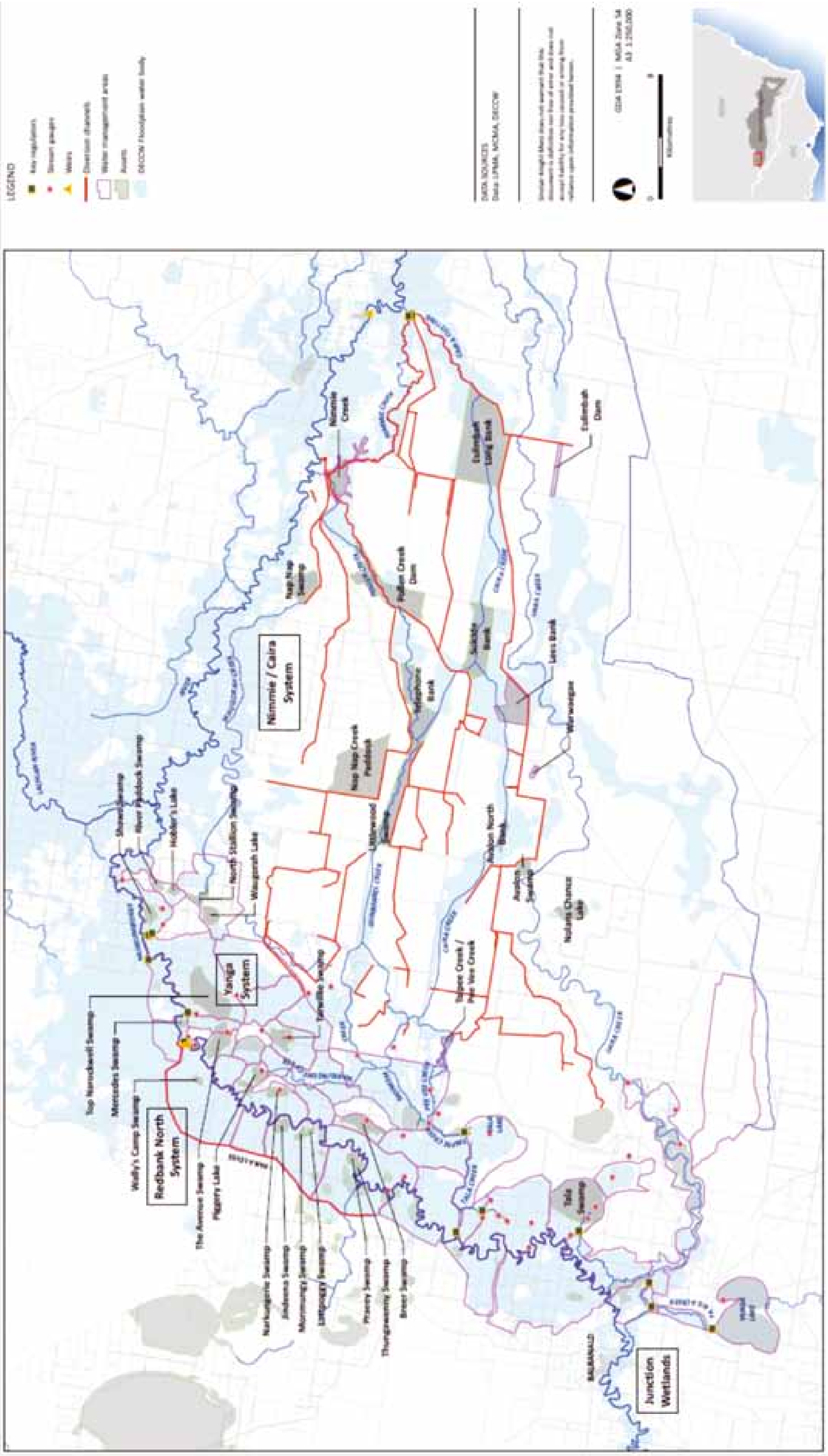


Figure 12: The Nimmie-Caira channel system.

The travel time from the Maude offtakes to Yanga is 10 days when the channels are fully wetted, which requires two to three weeks and up to 5,000 megalitres of water. Approximately 60,000 to 70,000 megalitres of water is required to inundate key rookeries and other wetlands in the Nimmie-Caira system, and sustain a bird breeding event.

Water Allocation Tier System

Water is allocated within the Nimmie-Caira system based on the 'Tiered Allocation' system. This system is not defined by legislation or state government policy, but has been developed collaboratively by the Nimmie-Pollen League of landowners and SWC to share water equitably within Nimmie-Caira. As such, it relies on the continuing willingness of the landholders to participate in the league. The location of the various tiered allocation lands is depicted at Figure 13.

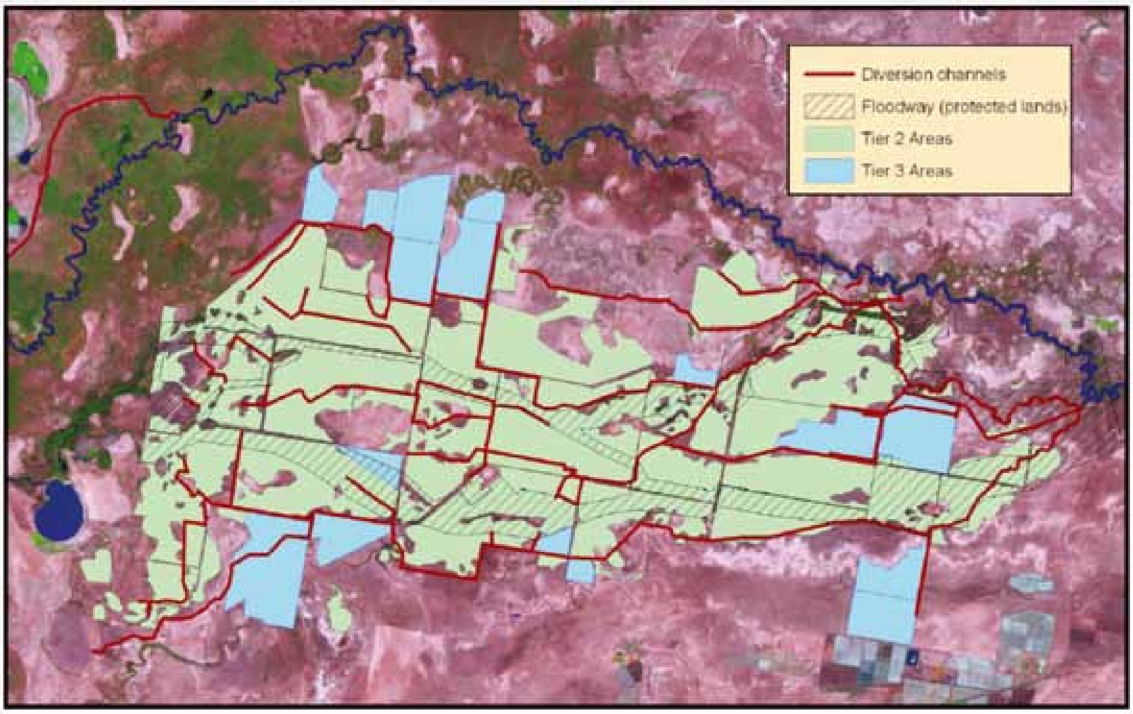


Figure 13: Nimmie-Pollen League tiered allocation and protected lands.

While the Tiered Allocation policy describes basic principles for how the system should operate, there is still a large amount of interaction between SWC and landholders in deciding how to operate the system in any given year. From an environmental management perspective, the system operation can be summarised as follows:

- Tier 1A: Diversion of water throughout the Nimmie-Caira system to fill up stock and domestic supplies. This is done through well-defined creeks and constructed channels, and generally requires a total of about 5,000 to 10,000 megalitres to fill all 75 dams and tanks. These diversions also provide some environmental benefits by providing refuge to some species during drought periods.
- Tier 1B: Watering of the complete length of floodway between Maude and Tala Lake. This is done by running water through the Nimmie and Caira sides of the floodway with all regulators open. This generally requires about 30,000 megalitres to produce inflow into Tala Lake, at which point Tier 1B is considered satisfied. Note that the outlet regulator from Eulimbah Swamp is initially closed in Tier 1B to accumulate inflow. Once sufficient head is built up within the swamp, the regulator is opened to provide an increased peak flow downstream, allowing the volume to wet a wider section of the floodway.
- Tier 2: Once wetting of the floodway is complete and there is sufficient water in the floodway

to produce flow into Lake Tala, Tier 2 watering commences. This involves splitting inflows equally between the Nimmie and Caira sides of the system, and running the diverted water through constructed channels and into irrigation bays. The water is then progressively held and moved through different bays to saturate the soil column. This may involve draining bays into the floodway, recapturing flows into channels and rediverting water into other bays downstream.

- Tier 3: Tier 3 watering commences when Tier 2 watering is complete or when sufficient water is known to be available to satisfy both tiers.

Note that Tier 1B requires watering of the complete length of floodway in preference to diversion of water for watering cropping bays. Consequently, the floodway receives water on a relatively consistent basis when any diversions from the Murrumbidgee River are available.

In addition to Tier 1B water, the floodway in the Nimmie-Caira system receives water on an ongoing basis during periods of Tier 2 and Tier 3 allocation, either through drainage flows or through landholders carrying out discretionary environmental watering. Once a group of cropping bays have been watered, the water is generally drained into the floodway prior to being recaptured in diversion channels and diverted into other bays further downstream. A proportion of this water is retained in depressions in the floodway which cannot be drained, increasing the amount of water available in the floodway. Landowners may also decide to fill or top-up certain rookery areas in the floodway, or divert water further into swamp areas within their own properties using Tier 2 or Tier 3 water.

4.6.2.2 Yanga

Natural flooding of Redbank occurs when the Murrumbidgee flow in the vicinity of Redbank Weir exceeds 9,000 ML/d (J Maguire (OEH) 2011, pers. comm., 28 October). Redbank Weir was constructed to permit controlled inundation in response to concerns regarding the reduction in floodplain watering arising from river regulation. There has been a significant reduction in the occurrence of high flow events large enough to spill into the Redbank system. Most flows are therefore in the form of diversions, which are permitted only when natural flood events in the upper Murrumbidgee River produce flows that cannot be captured by upstream storages, or when environmental water is available. Watering is now reliant on environmental flows and agricultural irrigation (artificial watering). It is delivered to Yanga through Yanga and Waugorah regulators. Figure 14 depicts the location of main flow paths and regulators in Yanga.

Regulated inflows to Yanga are primarily from the Yanga and Waugorah regulators. The Waugorah regulator has a capacity of 50 to 200 ML/d, whilst the Yanga regulator has a capacity of 400 to 1,000 ML/d. Capacities vary based on upstream weir pool level, river flow rate, water levels downstream of the regulator and vegetation growth in the Top Narockwell wetland complex. Mercedes Swamp is watered via a separate regulator that connects directly to the Redbank Weir pool, which has a maximum flow rate of 50 ML/d.

The Waugorah Regulator discharges into a channel which runs south-east through Shaw's Swamp and into Irrigation Lake at the eastern edge of Yanga National Park. Water diverted through the Yanga Regulator discharges onto the main floodplain and drains southwards, through depressions and swamps such as Piggery Lake, Tarwillie Swamp, Narkungerie Swamp and Breer Swamp. Sustained flow may provide sufficient volume for water to reach as far south as Monkem Creek, Tala Creek and beyond. A volume of at least 50,000 megalitres is required fill up the wetlands and depression between the Yanga regulator and Tala Lake. This would require approximately two months with the Yanga regulator operating at close to full capacity.

Yanga Lake can receive water directly from the Murrumbidgee through Yanga Creek, or from Uara Creek through Devils Creek. A number of internal levees and regulators have been constructed to control flows, allowing different portions of Yanga to be watered at different times depending upon water availability and water requirements.

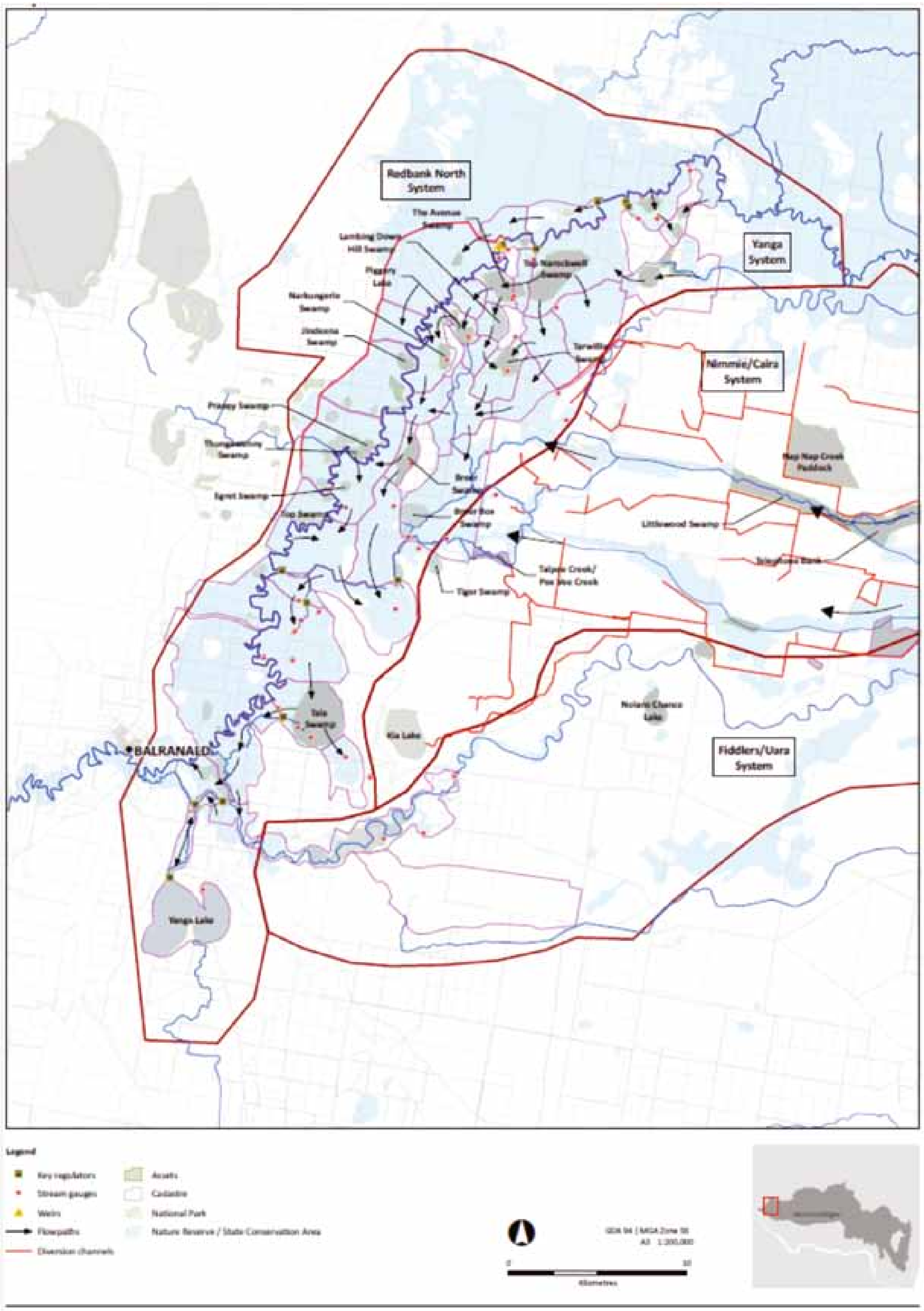


Figure 14: Main flowpaths and regulators in Yanga.

The Nimmie-Caira system can be used to supply water to the southern portion of Yanga because it is more direct than supply from the Yanga and Waugorah regulators. This is because the Nimmie-Caira system contains more efficient channels, whereas the flow paths in the Yanga system floodplain are mainly ill-defined swales. Large flows in the White Elephant Canal can overflow into the floodplain north and east of Tarwillie Swamp. Large flows in Monkem Creek, Deadmans Creek and Pee Vee Creek drain into Talpee Creek and into the semi-permanent Tala Lake (DLWC 2000). On rare occasions, enough water may flow south along the floodplain to reach Tala Creek, which runs from Tala Lake into the Murrumbidgee River. In large events, some water may end up in Tala Lake through Tala Creek, and yet others in Woolshed Creek (which flows south towards Yanga Lake) via a levee and regulator. These control the amount of flow which can run through Woolshed Creek.

In this system the internal channel capacities are not limiting, it is the capacity of the regulators that control the rate of progression of inundation.

4.6.2.3 North Redbank

In its natural state North Redbank is watered by overbank flows. Diffuse natural creek lines run across the floodplain, spreading floodwater into depressions and swamps. The only well-defined channel is the Redbank North Channel along the Paika Levee.

Water is diverted into the northern Redbank floodplain through the Glen Dee and Juanbung regulators. Excess water returns to the Murrumbidgee River through the Baupie and Wynburn Escape regulators. Offtake regulators located along the channel distribute water into the floodplain. This water enters natural drainage lines that run south towards the river. However, levees prevent water from returning to the river.

Prior to the construction of the Paika Levee, floodplain flows also filled the Paika, Pitapunga and Macommon Lakes on the northern floodplain. However, these flows are now directed southwards towards Chaston's Cutting.

4.6.2.4 Water accounting

Water supplied by SWC is measured at the diversion offtake and any transmission losses to deliver the water to the offtake are not accounted against the entitlement holder. This means there will be no transmission losses accounted against environmental water accounts for water delivered to the bulk offtakes for Nimmie-Caira, Yanga or North Redbank. Any return flows, if suitably measured in drainage channels, could possibly be credited to the user in the future. However, there are not expected to be any return flows from environmental watering of the Lowbidgee. Return flows through environmental watering in this region should be a future management goal, pending improved metering and an appropriate return-flow policy.

4.7 Mid-Murrumbidgee Wetlands

4.7.1 Water resource requirements

The Mid-Murrumbidgee wetlands are inundated by flood events, with the frequency of inundation depending upon the elevation of the wetland and distance from the river. Historically, low-level wetlands and billabongs located close to the river would have flooded annually, while higher wetlands located further from the river would have been inundated every three to five years. The wetlands typically take six months to two years to dry out after a watering event (MDBA 2010).

The then DLWC established the commence-to-fill elevations (at the nearest streamflow gauging station) for 91 Mid-Murrumbidgee wetlands between Gundagai and Balranald (Table 13). Sinclair Knight Merz (SKM) estimated the approximate flow at Wagga Wagga to produce the flow at the reference station. The Murrumbidgee Catchment Management Authority (MCMA) has grouped the Mid-Murrumbidgee wetlands into four categories based on the flow magnitude required to commence filling and the estimated frequency of inundation under natural and current conditions (Table 14) (MDBA 2010). The frequency of inundation for these wetlands has reduced due to regulation. If the aim of an environmental flow is to provide a more 'natural' high flow, then it is effective to augment natural flood events with strategic releases of environmental water from the two upper-catchment dams. This could be done to increase their duration (known as 'piggybacking') and in some smaller natural events to increase magnitude, staying below key thresholds such as the 32,000 ML/d threshold at Gundagai. These flows can promote natural riverine processes lost to river management and regulation. There are limitations to this strategy, however, which are dealt with in Section 4.7.3.

Table 13: Commence-to-fill flows for some of the important wetlands in the Murrumbidgee River system, at the next nearest reference gauging station. (Source: James Maguire 2010)

Wetland	Reference Gauging Station	Commence to Fill Flow (ML/d)*
Eringoarah Lagoon North	Wagga Wagga	29,100
Eringoarah CSU Lagoon	Wagga Wagga	29,100
Kurrajong Lagoon	Wagga Wagga	34,200
Eunony Bridge Lagoon (Chick Kelly)	Wagga Wagga	43,000
Eunony Reserve Lagoon	Wagga Wagga	30,000
Parkan Pregan Lagoon	Wagga Wagga	42,000
Gobbagombalin Lagoon	Wagga Wagga	47,000
Flowerdale Lagoon	Wagga Wagga	42,700
Pomingalarna	Wagga Wagga	22,600
Kelvin Grove—Western End	Wagga Wagga	45,000
Island Lagoon	Wagga Wagga	23,200
Sheepwash Lagoon	Wagga Wagga	29,000
Bellevue Reserve Lagoon	Wagga Wagga	34,000
Iris Park Swamp	Wagga Wagga	25,400
Iris Park Lagoon	Wagga Wagga	23,200
Ganmain Station 1	Wagga Wagga	29,200
Ganmain Station 2	Wagga Wagga	31,000
Ganmain Station Ponds	Wagga Wagga	29,200
Berryjerry Lagoon	Wagga Wagga	16,700

Wetland	Reference Gauging Station	Commence to Fill Flow (ML/d)*
Bulgari Lagoon	Wagga Wagga	70,400
Bulls Run 1 / Clarks Sandhill Lagoon	Wagga Wagga	23,200
Bulls Run Swamp	Wagga Wagga	61,100
Bulls Run 2 (Weirs)	Wagga Wagga	31,500
Deepwater 1	Wagga Wagga	30,600
Matong Lagoon	Wagga Wagga	29,700
Deepwater Swamp / Lake	Wagga Wagga	61,100
Deepwater Lagoon 2	Wagga Wagga	28,000
Wauberrima Lagoon	Wagga Wagga	29,000
Buckingbong Depression	Wagga Wagga	38,200
Below Dixons Dam / Creek Swamp	Wagga Wagga	38,200
Berembed Lagoon	D/S Berembed Weir	23,000
Green Valley	Narrandera	44,200
Narrandera State Reserve	Narrandera	21,800
Narrandera State Forest	Narrandera	26,800
Markeys Beach Lagoon	Narrandera	23,700
Molly's Lagoon	Narrandera	21,400
Dry Lake	Narrandera	22,500
Euroley Lagoon	Narrandera	39,100
Yanco Ag Lagoon	Narrandera	39,100
Turkey Flats	Narrandera	43,500
Euwarderry Lagoon	Narrandera	24,500
Horseshoe Lagoon	Darlington Point	20,000
Kenlock Lagoon	Darlington Point	20,000
Yarramungueer Lagoon	Darlington Point	18,000
Gooragool Lagoon	Darlington Point	15,434
Mantangry Lagoon	Darlington Point	18,000
Stick Lagoon	Darlington Point	20,000
Ungundury Lagoon	Darlington Point	20,000

Wetland	Reference Gauging Station	Commence to Fill Flow (ML/d)*
Cuba Horseshoe Lagoon	Darlington Point	20,000
Darlington Lagoon	Darlington Point	21,700
Sunshower Lagoon	Darlington Point	16,000
Waddi Creek Lagoon	Darlington Point	20,000
Darlington Point Lagoon	Darlington Point	49,100
Dunoon Lagoon	Darlington Point	18,000
Wowong Lagoon	Darlington Point	16,000
Yarradda Lagoon	Darlington Point	16,000
Benerembah State Forest Lagoon	Darlington Point	16,000
Yarradda State Forest Lagoon 1	Darlington Point	17,000
Yarradda State Forest Lagoon 2	Darlington Point	18,500
Homestead Lagoon	Darlington Point	12,100
Groongal Lagoon	Carrathool	10,300
McKennas Lagoon	Carrathool	12,400
Dinnys Lagoon	Carrathool	11,000
Cooey Point Lagoon	Carrathool	12,400
Gre Gre Lagoon	Carrathool	11,000
Boonari Lagoon	Carrathool	20,000
Six Mile Reserve Lagoon	Carrathool	12,000
Bevendale Lagoon	Carrathool	16,000
Brandons Bend Reserve Lagoon 1	Carrathool	15,000
Brandons Bend Reserve Lagoon 2	Carrathool	20,000

** This data was generated by cross-referencing aerial photography and landsat imagery of flood events in the Murrumbidgee River catchment, with gauged river flows for the same event. Hence the data presented is indicative only of commence-to-flow levels for wetlands in the Murrumbidgee River floodplain.*

The Murray-Darling Basin Authority (MDBA) developed an environmental watering target for the Mid-Murrumbidgee wetlands aimed at increasing the frequency of inundation (Table 14). For example, a flow of 27,000 ML/d at Wagga Wagga, which inundates low-level wetlands, occurred naturally with an average recurrence interval of 1.5 years, but now occurs every 2.1 years. The objective is to enhance natural flow events so that the frequency of events with a flow magnitude of 27,000 ML/d (or greater) reduces to 1.7 years (MDBA 2010).

Table 14: Environmental water targets for Mid-Murrumbidgee wetlands. (Adapted from MDBA 2010)

Flow rate at Wagga Wagga (ML/d)	Duration (days)	Timing	Natural ARI[#] (years)	Current ARI (years)	Target ARI (years)
27,000 (low floodplain level)	5	June to November	1.5	2.1	1.7
35,000 (mid-floodplain level)	5		1.8	3.2	2.5
44,000 (mid-floodplain level)	3		2.3	4.3	2.9
63,000 (high floodplain level)	3		4.8	8.3	6.7

 # ARI: Average Recurrence Interval

These flow-augmentation events will occur on an opportunistic basis, but it is estimated that the total volume of environmental water required to augment typical river flows to achieve the watering targets in Table 14 is approximately 35,000 to 40,000 ML/yr, with wetlands located further down the system requiring greater equivalent flows at Wagga Wagga to commence-to-fill.

4.7.2 Operating regimes

The watering strategy for the Murrumbidgee River is to augment natural flow events to increase both their duration and where appropriate, their magnitude. The aim is to increase the frequency of inundation of wetlands distributed across the Mid-Murrumbidgee floodplain.

Flow augmentation will be most effective if the various sources of environmental water are collaboratively managed. This includes entitlements held by the Australian Government and entitlements held by the state and the Environmental Water Allowance (EWA 1, 2, and 3). While the EWA accounts accumulate water under all conditions, there are significant increases in EWA volumes when the General Security water determination reaches 0.6 ML/share (EWA1) and 0.8 ML/share (EWA3). In addition, when Burrinjuck Dam is above 50 per cent full, a larger proportion of water is released under the Water Sharing Plan dam translucency rules.

These EWAs mean the Water Sharing Plan makes significantly more water available to the environment at higher General Security water determinations. Furthermore, climate conditions producing fuller dams and enabling higher General Security water determinations are also likely to mean higher rainfall over tributaries downstream of the dams, and more tributary run-off.

Flow augmentation depends on flow generated in tributaries that join the Murrumbidgee River downstream of Blowering and Burrinjuck Dams. In very dry years the ability of the tributaries to generate events suitable for augmentation is significantly reduced. The amount of tributary run-off generated by rainfall between July and November strongly depends on how wet the catchment already is. Much larger volumes of rainfall are required to produce flow into the river in dry periods. This means that suitable tributary events are much rarer and flow augmentation significantly more difficult and unpredictable. Conversely, in very wet years the Mid-Murrumbidgee wetlands may receive sufficient watering from natural flooding events. Therefore flow augmentation will generally focus on years that are neither very dry nor very wet.

Modelling to test the number of Mid-Murrumbidgee wetlands inundated at various release, baseflow and tributary inflow scenarios provides data on the interaction between Tarcutta Creek and Murrumbidgee River flow levels (Parsons Brinkerhoff 2009). The modelling shows that inflows from Tarcutta Creek are influential in determining the number of wetlands inundated (Table 15). In terms of this study, the data provides an indication of the required flow levels in Tarcutta Creek before initiating an event.

Table 15: Summary of the number of Mid-Murrumbidgee wetlands expected to commence-to-fill under various flow scenarios. (Source: Parsons Brinkerhoff 2009)

Release Volume (GL)	Upper Baseflow (ML/d)	Tarcutta Peak Inflow (ML/d)	Total Number of Wetlands CTF	Percentage of 91 Wetlands
40	2,000	5,000	6	7
40	2,000	15,000	14	15
60	2,000	5,000	10	11
60	200	15,000	21	23
80	2,000	5,000	23	25
80	2,000	15,000	29	32

The objective of a flow augmentation event is to create a flow of at least 27,000 ML/d at Wagga Wagga for a period of three to five days. The flow at Wagga will be made up of tributary inflows and dam releases, which may (but ideally wouldn't) include releases to meet irrigation orders as well as environmental releases. Hence, the total volume and rate of environmental release required will vary from event to event. A number of triggers should be considered in determining if an event is suitable for flow augmentation. These include:

- the time of the year (i.e. the most commonly targeted period would be between May and October)
- volume of environmental water available
- forecast rainfall
- current catchment wetness
- current run-off
- dam release capabilities
- a low irrigation demand
- rainfall rejection of regulated water in the system (especially early in the irrigation season)
- timeframes for the release of EWA account water before it is forfeited
- risks to the public and infrastructure.

These suggested triggers are illustrated in Figure 15, while further discussion is provided below.

4.7.2.1 Operational considerations

- **Current dam orders and river state:** During times of peak irrigation demand in mid-late spring, irrigation orders can increase daily river flows to above 20,000 ML/d at Wagga Wagga. This increases the underlying baseflow upstream of the main irrigation area offtakes (Berembed and Gogeldrie Weirs), and potentially further downstream if a rain-rejection event occurs. Irrigation flows alone are not sufficient to use for flow augmentation as they are extracted too high in the river system for a significant benefit to most wetlands. However, if a tributary event occurs while orders are in the river, this will increase the effectiveness of any augmentation releases. These benefits will only be to Berembed/Gogeldrie (unless there are rainfall rejections).

- **Likelihood of supplementary flow announcements:** Announcements are made by the NSW Office of Water in consultation with SWC. The announcement and volume likely to be taken by diverters depends on the current General Security water determination and extent of rainfall (primarily in the irrigation areas). If an announcement is likely, then flow augmentation would not be attractive, unless agreement can be reached to delay the announcement until after the wetland watering has taken place. Also, management of environmental water to ensure it is shepherded through the system without extraction would be required.
- **Flow constraints:** The SWC Water Supply Work Approval stipulates channel capacity constraints for key water courses in the Murrumbidgee Catchment. A major constraint in the river is the Tenandra Bridge at Mundarlo which causes operators to restrict river flows at Gundagai to 32,000 ML/d (WSP 2003). Flows less than this may also be problematic if the tributaries are running higher than expected. In addition, flows in the Tumut River are generally restricted to less than 9,300 ML/d at Tumut to minimise bank erosion and localised flooding.

4.7.2.2 Likelihood of suitable tributary flow

- **Catchment wetness and variable response to rainfall:** Tributary catchment response is highly dependent on catchment wetness. The run-off hydrograph resulting from a volume of rainfall can vary widely depending on the time of year and the climate over the previous months and years. It is recommended that the modelled soil moisture compared against historical averages be used to predict the likely catchment response. Flow augmentation should only be considered in keeping with modelled natural flows in the catchment.
- **Recent events:** The probability of tributary flow occurring is significantly increased if a rainfall event has occurred in the one to two weeks preceding the rainfall event that will be used to piggyback. In addition to increasing overall catchment wetness, such events fill surface depressions and the top layers of the soil profile, thereby reducing initial losses of rainfall and increasing the rate and volume of storm run-off.
- **Environmental flows at dams:** The effect of translucency rules on Burrinjuck and Blowering Dam outflows as prescribed in the Water Sharing Plan should also be considered. If heavy rainfall is expected and a significant translucency release is prescribed by the plan, this should be taken into account when considering an augmentation release, and whether a release should be delayed until the end of the event to meet Gundagai constraint requirements and to extend inundation downstream.

Figure 15: Key drivers influencing flow augmentation in the Murrumbidgee River system. (Source: CSIRO 2008)

General Security WD	0	35	50	55	60	65	70	75	80	85	90	95	100
Percentile of time GS WD at end of Water Year less than this value, based on current WSP rules*	-	1	5	9	13	19	28	38	44	46	49	50	51
Environmental availability		Extreme drought		Mild drought			Water scarce			Dry condition		Average condition	
MI Conveyance			Increasing from 60 GL at 0 WD						Fixed at 243 GL				
CI Conveyance	111.6 GL						Increasing to 130 GL at 100 WD						
Supplementary Diversions				Announced diversions up to maximum volume					Restricted to 0.85 ML/share inc GS			No supplementary flows	
Burrinjuck Translucency													
Dams < 30% full				Translucency restricted to at most 50% of inflows - all catchment conditions							Full translucency		
Dams between 30% and 50% full				Translucency restricted to at most 50% of inflows - normal catchment condition only							Full translucency		
Dams > 50% full											Full translucency		
Environmental Water Allowance													
EWA1			No EWA1 unless carried over						EWA1 up to 50 GL				
EWA2							EWA2						
EWA3					No EWA3						EWA3 up to foregone translucent release limit		
Chance of > 400 GL above 20 GL/d at Wagga Wagga between July and October (indicator of level of environmental supply)	Very small				Unlikely					Less likely		Likely	
Historical number of events > 30,000 ML/d at Wagga Wagga July - October in one year					0-1						1-3		
Flow augmentation benefit			Suitable event unlikely and volume required expensive					Augmentation most beneficial				Minimal additional benefit	
Artificial watering effectiveness		Possible at few sites		Possible at selected sites				Possible over wide range of sites				Limited benefit	

4.7.2.3 Release management

- **Available environmental volume:** Large volumes of water (of the order of 50,000 megalitres) are required to make a successful augmentation event, and a large proportion of this will be required to increase water levels in the river to enable spilling into wetlands, rather than ending up in the wetlands itself.
- **Initiating an event:** The decision to release flows to augment a natural flood event needs to be taken early, if the releases are to arrive in time to augment the peak flows. Therefore the decision needs to be based on stream flows recorded in the headwaters of tributary catchments, taking into account recent and forecast rainfall.
- **Release hydrograph:** As the tributary inflows are not known prior to an event, the impact of augmentation flows at the time of their release can only be roughly known. If an event is short, the augmentation release is unlikely to raise the peak flow but can extend the duration of higher flows. If an event turns out to be longer, the release is more likely to increase peak flows. Scenario modelling suggests that small, very early releases are a useful strategy, as they are an efficient way to increase the peak of the hydrograph and can be followed up by larger releases once the magnitude of the tributary event is clear.
- **River reach attenuation:** In any flood event, the peak flow at points downstream of Wagga Wagga depends on both the peak flow and duration of flow at Wagga Wagga. Peak flows which are only maintained for a short period at Wagga Wagga are quickly attenuated, whereas longer peak flows are attenuated much less rapidly as they move downstream. This means sustained flows of several days duration at Wagga Wagga are required to inundate the wetlands higher on the floodplain.

It should be noted that SWC is currently developing a computer program to assist with river operations (Computer Aided River Management—CARM). The program will be capable of reading rainfall, river flow and diversion data in real time, forecasting tributary flows and estimating transmission losses for current conditions. This model will operate at an hourly timescale (or less) and will be suitable for estimating releases required to achieve a successful flow augmentation event. The software is scheduled for implementation by 2012. Currently, SWC operates the river using a spreadsheet-based model known as CAIRO, which operates on a daily time step. This model does not include routines to estimate tributary inflows or to estimate transmission losses. Instead, these are estimated by operators based on past experience with similar flow events.

There have been three flow augmentation events since 1998. The decision on whether an event was likely to be successful was taken based on advice from the river operator, taking into account catchment 'wetness', current tributary flows and current rainfall. The most recent piggyback event occurred in September 2010. Approximately 47 gigalitres was used to keep flows at Wagga Wagga above 40,000 ML/d for four days.

4.7.2.4 Water accounting

When a flow augmentation event has been managed to target the Mid-Murrumbidgee wetlands, it is expected that a majority of these releases will remain in-stream and be available for downstream uses, such as watering the Lowbidgee Floodplain. The volume of residual water will need to be assessed on an event-by-event basis. A method for assessing the volume of residual environmental water will need to be developed in consultation with SWC, based on observed flow hydrograph volumes measured at key locations and accounting for tributary inflows, irrigation diversions and drainage return flows. It is expected that the necessary information would be contained in the updated CARM system which will be used by SWC to assist in the daily river operations.

If environmental water managers choose to pass any residual water from flow-augmentation events downstream into the Murray River then it will be necessary to concur with the MDBA and southern basin states, and NSW Office of Water on a method to tag this water and shepherd it through the system, accounting for transmission losses.

4.7.3 Operational constraints and opportunities

There are constraints on maximum flow rates in the Murrumbidgee River between Burrinjuck Dam and Wagga Wagga. Based on historical test releases in the 1980s, low-lying land around Gundagai and the Tenandra Bridge at Mundarlo is flooded at river flows just above 32,000 ML/d (WSP 2003). In addition to the constraints in the Murrumbidgee River around Gundagai, there are also limitations on flows in the Tumut River downstream of Blowering Dam. The River is managed to restrict channel flows to less than 9,300 ML/d at Tumut to minimise bank erosion, constraining the possible role of Blowering Dam in augmenting downstream flows (WSP 2003). The SWC Water Supply Work Approval also stipulates channel capacity constraints for key water courses in the Murrumbidgee Catchment.

The flow constraint at Gundagai is of particular relevance to flow augmentation planning, as it constrains the amount of water that can be released from the dams if there is significant run-off from the major tributaries between the dams and Gundagai (the Goobarragandra River, Jugiong Creek, Muttama Creek, Gilmore Creek and Adjungbilly Creek). This means run-off from the tributaries downstream of Gundagai (Tarcutta Creek, Hillas Creek and Kyemba Creek) is very important in flow-augmentation events.

Flow-augmentation however, may be enhanced during times of peak irrigation demand in mid-late spring, as irrigation orders can increase daily river flows to greater than 20,000 ML/d at Wagga Wagga. Irrigation flows alone are not sufficient to use for flow augmentation but they may enhance a flow-augmentation event, although the benefits will only be for wetlands located upstream of the main irrigation diversions (that is, those upstream of Berembed and Gogeldrie weirs).

4.8 Floodplain Wetlands: Balranald to Murray River Junction

4.8.1 Water resource requirements

There is relatively little information available regarding water use and management downstream of Balranald. Management actions are considered to be complex due to the difficulty of inundating the wetlands downstream using only flows from the Murrumbidgee River. High baseflows in the Murray River as well as upstream releases from Murrumbidgee storages are needed to supply the water required to maintain these wetlands. It is necessary, therefore, to manage Murrumbidgee River flows to synchronise with high Murray River flows. Due to the nature of the wetlands and the absence of weirs for diversions, high river heights are essential to inundate these downstream assets. Delivery of more than 5,000 ML/d downstream of Balranald, in addition to a Murray River flow greater than 10,000 ML/d at Barham for a period of several weeks is considered necessary to inundate the wetlands (J Maguire (OEH) 2011, pers. comm., 9 August). However, a period of nil or reduced diversions upstream of Balranald may (at times) be required, which could compromise the watering requirements of Lowbidgee assets.

The Water Sharing Plan for the Murrumbidgee Regulated River Water Source (2004) established minimum end-of-system flow requirements of 200 ML/d when allocations and carryover are below 80 per cent of share components. Otherwise, 300 ML/d is released from the Balranald Weir for the first four years of the plan and increased flows thereafter to reflect a more natural flow. These flows are to be protected from extraction to ensure connectivity throughout the system and reintroduce a more natural flow pattern. In June 2008, as part of emergency measures introduced in response to the drought, flows decreased to as low as 41.5 ML/d for a couple of days. Flows also dropped substantially below target from mid-August to late September 2009.

4.8.2 Operating regimes

Manie Station Lagoon and Pelican Lagoon occur on the floodplain immediately north of the Murrumbidgee River, while the remainder are watered via anabranch creeks which extend north and west into the delta formed by the Murrumbidgee and Murray Rivers (Figure 6). Waldaira Lake receives inflows from Waldaira Creek, which is a tributary of Manie Creek. Bulumpa Lagoon is watered via Jack O'Brien's/Middle Creek. Chalmers Lagoon has its own small catchment, but is also watered via Manie Creek. Peacock Creek Flora Reserve includes Peacock Creek and a 97-hectare portion of the floodplain between it and the Murray River. This creek begins at the confluence of Manie and Jack O'Brien's/Middle Creeks, with the Flora Reserve occurring at the western-most reach of Peacock Creek, near the Murray River.

4.8.2.1 Existing and proposed water delivery infrastructure

The only regulating structure in this reach is the Balranald Weir, which is primarily used for stock and domestic water supply. The channel capacity downstream of Balranald is estimated to be 11,000 to 13,000 ML/d (SKM 2008). The volume of flow decreases from Balranald, with only a small volume of water making it to the junction with the Murray River. Due to the absence of weirs for diversions downstream of Balranald, high river levels are necessary for inundation of the river-fed wetlands.

A study is required to determine the required river level for commence-to-fill for each of the river-fed wetlands requiring inundation.

4.8.2.2 Water accounting

Information allowing an estimation of loss volumes downstream of Balranald is minimal and losses are assumed to be negligible in existing models. Further assessment of losses is required in this reach to ensure sufficient water is delivered to allow for the inundation of wetlands downstream of Balranald.

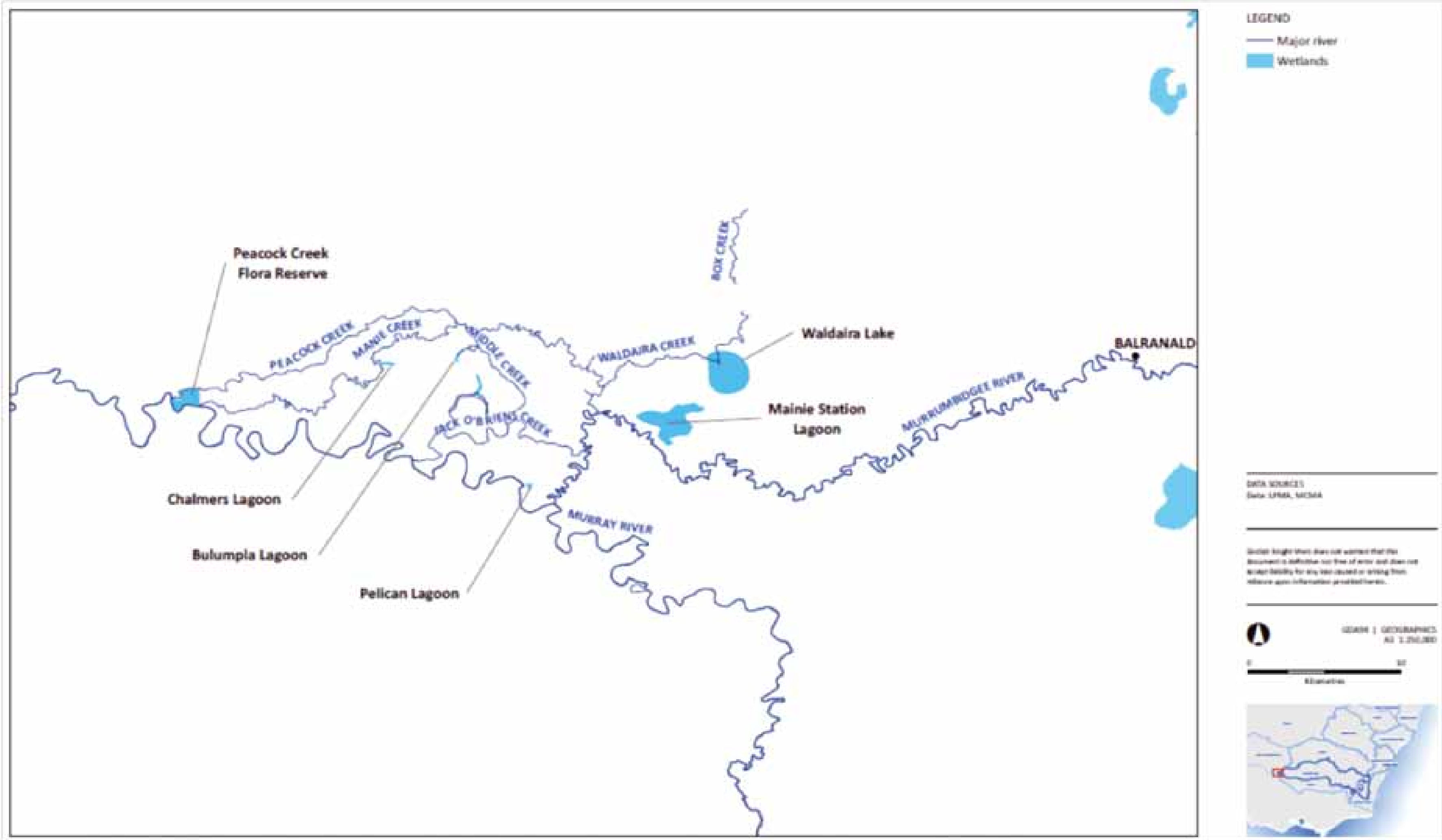


Figure 16: Location of key creeks and lagoons in the Balranald to Murray Junction reach of the Murrumbidgee River.

4.9 Summary of water resource requirements

Table 16 lists the water management areas and provides a summary of their water demands. The relevant ecological objective (from Table 4) is listed for each asset, along with the most ecologically appropriate timing for flows, and the water demand required to meet them. Please note that where possible specific information has been provided, but not all areas in the Murrumbidgee River catchment have been well-studied. For example, the data is relatively robust for the Mid-Murrumbidgee wetlands, and comparatively poor for wetlands downstream of Wanganella Swamp in the Yanco Creek System, and downstream of Balranald. These latter areas require further investigation to accurately determine their water requirements.

Table 16: Key water management areas and their associated water demands

Water Management Area	Site	Ecological Objectives	Timing	Water Resource Requirement
Mid-Murrumbidgee Wetlands (Gundagai to Maude)	Low-floodplain wetlands	Maintain and improve wetland vegetation communities.	Winter-spring	Should a suitable piggyback event occur, seek to exceed 27,000 ML/d at Wagga Wagga to inundate low-lying Mid-Murrumbidgee wetlands, or use irrigation infrastructure to inundate prioritised Mid-Murrumbidgee River wetlands for at least three months.
		Maintain and improve river red gum forest and woodland communities.	Winter-spring	
	Mid-floodplain wetlands	Maintain and improve wetland vegetation communities.	Winter-spring	Should a suitable rainfall event occur (with a peak over 45,000 ML/d at Wagga Wagga) seek to create a more natural flow recession once flows are less than 30,000 ML/d at Gundagai, or use irrigation infrastructure to inundate prioritised Mid-Murrumbidgee River wetlands for at least three months.
		Maintain and improve river red gum forest and woodland communities.	Winter-spring	
	High-floodplain wetlands	Maintain and improve wetland vegetation communities.	Winter-spring	Should a suitable rainfall event occur (with a peak over 60,000 ML/d at Wagga Wagga) seek to create a more natural flow recession once flows are less than 30,000 ML/d at Gundagai, or use irrigation infrastructure to inundate prioritised Mid-Murrumbidgee River wetlands for at least three months.
		Maintain and improve river red gum forest and woodland communities.	Winter-spring	

Water Management Area	Site	Ecological Objectives	Timing	Water Resource Requirement
MIA	Fivebough Swamp	Maintain open water areas and exposed muddy margins.	Late summer-autumn	Approximately 500 ML delivered via MI irrigation channels. Allow for 5–20 per cent transmission loss. For operational purposes the best time for delivery of water is July to October.
		Maintain and improve wetland vegetation communities.	Late winter-spring	
	Tuckerbil Swamp	Maintain and improve wetland vegetation communities.	Late winter-spring	500 ML delivered via MI irrigation channels. Allow for 5–20 per cent transmission loss. The most favourable timing for watering is July to October.
	Barren Box Swamp	Maintain and improve black box woodland.	Late winter-spring	3,000–5,000 ML delivered via MI irrigation channels. Allow for transmission loss. For operational purposes the best time for delivery of water is July to October.
	Lower Mirrool Creek Floodplain	Maintain and improve black box woodland.	Late winter-spring	Further work is required to determine volumes required for floodplain inundation under wet and dry antecedent conditions. For operational purposes the best time for delivery of water is July to October. Note the transmission losses depend on timing, with losses as low as 10 per cent possible.

Water Management Area	Site	Ecological Objectives	Timing	Water Resource Requirement
Yanco Creek system	Yanco Creek (including Upper Yanco Creek Floodplain Wetland complexes)	Maintain and improve river red gum forest and woodland communities.	Winter-spring	Further assessment required.
	Billabong Creek	Maintain and improve river red gum forest and woodland communities.	Winter-spring	Further assessment required.
	Forest Creek	Maintain and improve black box woodland communities.	Winter-spring	Further assessment required.
	Wanganella Swamp	Maintain and improve wetland vegetation communities.	Late winter-spring	1,500 ML required if delivered directly to inundate all 470 ha of Wanganella Swamp (Webster & Davidson 2010). Up to 20,000 ML is required if flows are delivered via Billabong Creek via the Murray Irrigation Limited system (E Wilson 2011, pers. comm., 19 September). Note: This amount does not take into account transmission losses and evaporation.
		Maintain open water areas and exposed muddy margins.	Late summer-autumn	
		Maintain known colonial waterbird breeding sites in 'event ready' condition.	Late winter-spring	
	Dry Lake	Maintain and improve river red gum forest and woodland communities.	Winter-spring	Further assessment required. However, flows in excess of 28,100 ML/d at Wagga Wagga will cause Molly's Lagoon and Dry Lake to commence-to-flow.
		Maintain and improve wetland vegetation communities.	Late winter-spring	
	Mundoora/Wilson Anabranch	Maintain and improve river red gum forest and woodland communities.	Winter-spring	Further assessment is required. However, flows in excess of 165 ML/d at Yanco Bridge will cause Wilson Anabranch to commence-to-flow. Mundoora Anabranch flows daily as it is the routed section for Yanco Creek.
	Kerribirri Swamp	Maintain and improve wetland vegetation communities.	Late winter-spring	Further assessment required.
	'Rhyola' Depressions and Flood-runners	Maintain and improve wetland vegetation communities.	Late winter-spring	Further assessment required.
	Box Swamp on 'Blue Gate'	Maintain and improve wetland vegetation communities.	Late winter-spring	Further assessment required.
	Breakout areas on 'Back Nullum'	Maintain and improve wetland vegetation communities.	Late winter-spring	Further assessment required.

Water Management Area	Site	Ecological Objectives	Timing	Water Resource Requirement
Lowbidgee Floodplain	Redbank North system	Maintain and improve river red gum forest and woodland communities.	Winter-spring	60,000 ML for high priority river red gum forests. 100,000 ML to water all of North Red Bank.
		Maintain and improve wetland vegetation communities.	Late winter-spring	Further assessment required.
	Yanga system	Maintain and improve river red gum forest and woodland communities.	Winter-spring	50,000–60,000 ML for high priority river red gum forests. 160,000 ML to inundate the entire Yanga floodplain.
		Maintain and improve wetland vegetation communities.	Late winter-spring	1,500–25,000 ML to water one or more assets.
	Nimmie-Caira system	Maintain and improve Lignum and other wetland vegetation communities.	Late winter-spring	Requires approximately 6,000–50,000 ML.
	Fiddlers-Uara system	Maintain and improve Lignum and black box woodland communities.	Winter-spring	Further assessment is required. However, approximately 15,000 ML diverted into the lower section of Fiddlers Creek from the South Caira/Warwaegae offtake regulator will water the western portion of Fiddlers Creek, and Yanga Nature Reserve.
		Maintain and improve wetland vegetation communities.	Late winter-spring	
Balranald to Murray River junction	River-fed wetlands	Maintain and improve wetland vegetation communities.	Late winter-spring	Requires delivery of >5,000 ML/d downstream of Balranald Weir in addition to Murray River flow >10,000 ML/d at Barham on the Murray River for a period of several weeks.
		Maintain and improve river red gum forest and woodland communities.	Winter-spring	

** As acknowledged in Section 3.3, the Murrumbidgee River channel is recognised as an asset; however its flow requirements are expected to be met (at least in part) by those delivered for the Mid-Murrumbidgee Wetlands, the Lowbidgee and river-fed wetlands between Balranald and the Murray River junction.*

4.10 Integrated water management

4.10.1 Carryover strategy

The Murrumbidgee Water Sharing Plan imposes strict limits on the amount of water that can be carried over from one season to the next. There are no carryover provisions for high security or supplementary entitlements, and 30 per cent of the general security allocation for any given year can be carried over to the next year. Any water not used, or included in the 30 per cent general security carryover provision, is included in the consumptive pool for the following season and is then distributed among users. If the storages spill, allocations may be set at 95 per cent and carryover provisions forfeited.

Environmental water managers have the opportunity to decide whether it is most beneficial to use all of the available allocation in a given year, whether some should be carried over to the following year, or whether to trade the water. The decision on whether to use the carryover provision will be influenced by a number of factors, such as how wet the current year is, the outlook for the next year, and what time in the year the allocation became available. Generally, the maximum benefit from environmental watering occurs in spring and autumn.

4.11 Opportunities to maximise environmental outcomes

The most beneficial outcomes for environmental watering will be achieved by coordinating the use of entitlements held by the Australian Government with entitlements held by the NSW Government plus the EWA account water. This requires coordination with OEH, who manages NSW Government entitlements, and EWA accounts.

When a flow-augmentation event takes place to water the Mid-Murrumbidgee wetlands, it is expected that a portion of these releases will remain in-stream and could be available for watering assets downstream such as the Lowbidgee Floodplain. The volume of residual water will need to be assessed and negotiated on an event-by-event basis. A method for assessing the volume of residual environmental water will need to be developed in consultation with SWC, based on observed flow hydrograph volumes at measured key locations and accounting for tributary inflows, irrigation diversions and drainage return flows. It is expected that the necessary information would be contained in the CARM water balance spreadsheet used by SWC to assist in the daily river operations.

4.11.1 Murrumbidgee Irrigation Area

The canals in the MIA are generally out of service for maintenance in the months of May and June and are consequently not available to deliver environmental water to assets such as Fivebough Swamp, Tuckerbil Swamp, Barren Box or Mirrool Creek. However, if watering is required at these times special arrangements may be negotiated with MI, with sufficient notice.

There may only be limited channel capacity to deliver environmental water during the peak irrigation season of November to February. Deliveries during this period will need to be coordinated with MI.

The MI-preferred period for environmental watering is either immediately prior to or after the peak demand period of November to February, as this avoids disruption to its winter channel maintenance period. MI has indicated that it would account the full transmission loss to environmental water managers for watering events in late winter and early spring, but would discount the accounting of loss for watering events that occur just prior to the irrigation season, as this would have been accounted against MI in wetting the channels for irrigation.

4.12 Opportunities for interaction with other assets in the Murray-Darling basin

The Murrumbidgee River discharges into the Murray River, just downstream of Balranald. Water can also be transferred to the Murray via the Yanco Creek System which discharges into the Edward River which then flows into the Wakool River, a tributary of the Murray River.

The Murrumbidgee and Lachlan River catchments are also connected, with end of system flows from the Lachlan River catchment passing into the Murrumbidgee River in the vicinity of Redbank. However, end of system flows are very rare, with most flows (including small-to-medium flood events) being incorporated into terminal wetlands such as the Great Cumbung Swamp. Lower Mirrool Creek Floodplain discharges into the Lachlan River during large flood events, but this also happens rarely.

5. Governance and Planning Arrangements

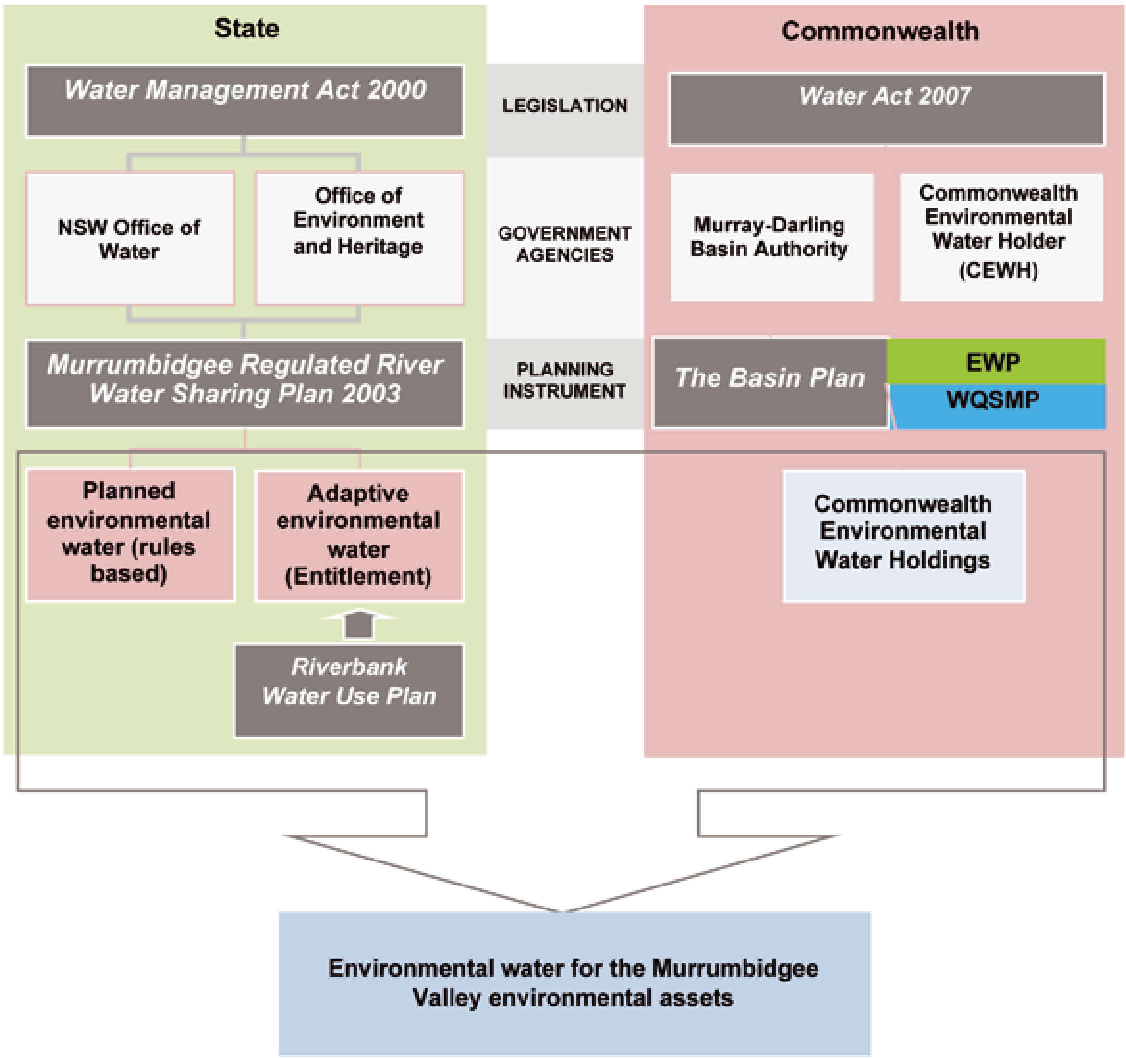
5.1 Overview of legislative instruments and policies

A number of legislative instruments and policies exist that are administered by Australian Government and agencies of states in the Murray-Darling basin. They include the following statutory and non-statutory documents:

- Council of Australian Governments (COAG) *Water Reform Agreement 1995*
- NSW SWC Management Outcomes Plan (SWMOP)
- Water Sharing Plans developed under the NSW *Water Management Act 2000* which reflect the broader objectives of the SWMOP. Relevant plans for the Murrumbidgee River catchment are:
  - *Water Sharing Plan for the Murrumbidgee River Regulated Water Source 2003* (NSW). This plan is currently being amended to include the Lowbidgee Floodplain and should be in place prior to the commencement of the basin plan.
  - *Water Sharing Plan for the Lower Murrumbidgee Groundwater Sources 2003* (NSW)
- State Water Corporation – *Water Supply Work Approval, Murrumbidgee Regulated River Water Source* (NSW Office of Water 2011).
- Riverbank Water Use Plan for managing state-held environmental entitlements in the Murrumbidgee (2008). This plan applies to the Murrumbidgee Regulated River Water Source as defined in the Water Sharing Plan. The plan authorises the use of water for environmental purposes throughout the Murrumbidgee Valley, and also applies to sections of the Lowbidgee floodplain within Yanga National Park, Yanga State Conservation Area, Yanga Nature Reserve and the Lowbidgee Flood Control and Irrigation District that can be watered by diversions from Maude Weir
- Murrumbidgee Regulated River Water Use Plan being developed by the NSW Office of Water
- Annual Environmental Watering Plans developed by OEH.

Figure 17 provides a summary of the relationship between environmental water made available through the *Water Management Act 2000* (NSW) (referred to as the WM Act) and the *Water Act 2007* (Commonwealth) (referred to as 'the Act'). These are some of the key statutory and non-statutory instruments that apply to the water resources of the Murrumbidgee Valley and facilitate environmental water management.

Figure 17: Overview of statutory arrangements for the provision of environmental water.



5.2 Water-sharing plans for the Murrumbidgee catchment

The key statutory instruments under the WM Act are water-sharing plans (WSPs). There are two WSPs for the Murrumbidgee Valley: *Water Sharing Plan for the Murrumbidgee River Regulated Water Source 2003* (NSW), and *Water Sharing Plan for the Lower Murrumbidgee Groundwater Sources 2003* (NSW). The WSP for the Murrumbidgee Regulated River Source specifies rules for planned environmental water and sets out the management of entitlements under adaptive environmental water. An amendment is under development to include the Lowbidgee Floodplain Control and Irrigation District, as it does not currently fall within the regulated river water source to which the WSP applies. However, it does fall within the Murrumbidgee Water Management Area as constituted by the Ministerial Order published in the NSW Gazette. The *Water Sharing Plan for the Murrumbidgee River Regulated Water Source 2003* (NSW) is complemented by the Riverbank Water Use Plan described in Section 5.3.

A principle function of the Regulated Water Source WSP is establishing environmental water requirements and the sharing of water between environmental and human needs. The plan also considers provisions outlined in Catchment Action Plans (CAPs), developed in accordance with the Catchment Management Authorities Act 2003 (NSW).

Objectives from Section 10, Part 2 of the WSP are:

a) protect and restore in-river and riparian habitats and ecological processes

b) provide for appropriate watering regimes for wetlands

c) sustain and enhance population numbers and diversity of indigenous species

d) protect basic landholder rights, as specified in the Water Management Act 2000, including native title rights

e) maximise early season general security allocations

f) protect town water supply

g) protect end-of-system flows

h) provide for commercial consumptive use

i) provide for identified recreational water needs

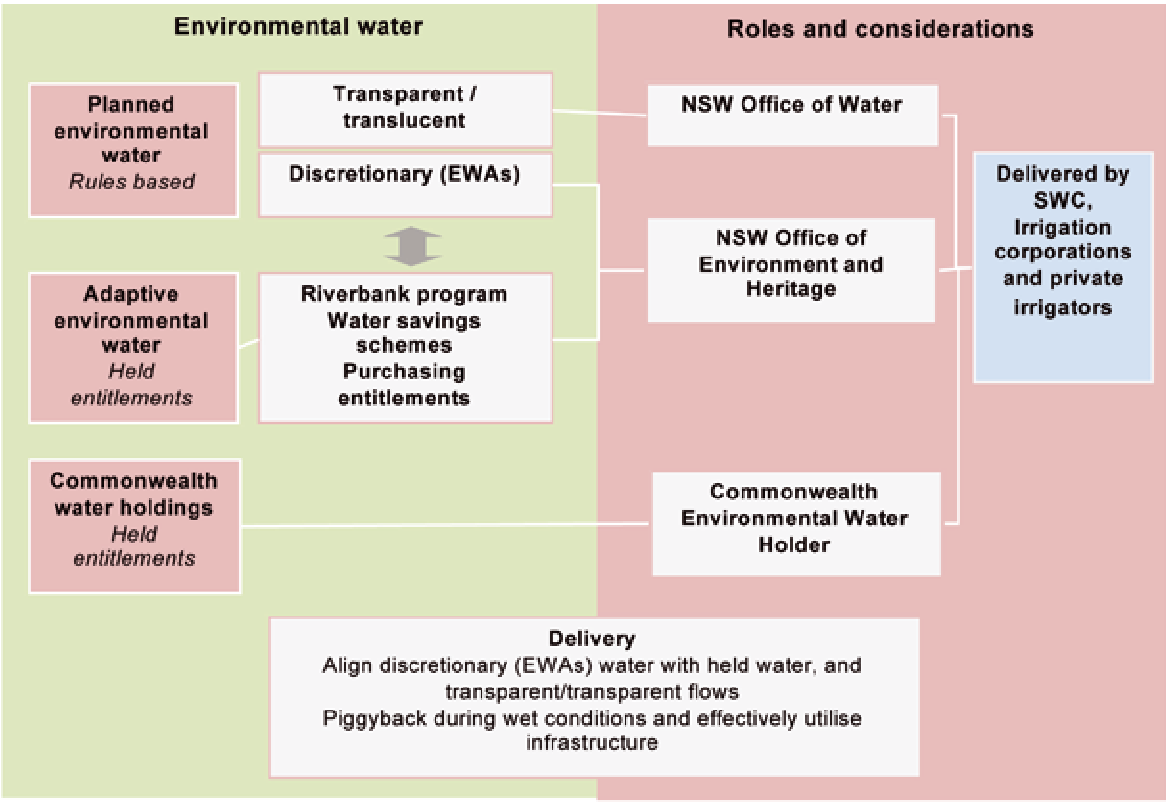
j) protect identified indigenous and traditional uses of water

k) within the ability of the plan promote the recovery of known threatened species.

Included in the plan is a description of environmental water for the defined water source; landholder water requirements; water extraction requirements; water access arrangements and bulk water access regime; limits on the availability of water; access rules; consideration of the effects of climate variability; and rules for prioritising water allocations associated with reduced water availability.

The WSP allows for two types of environmental water: planned environmental water which is rules-based, and adaptive environmental water which is dependent on held entitlements. The purpose of environmental watering is to achieve a more natural flow regime to improve the health of the river and associated wetlands, including increased fish migration and breeding, variability of flows and increased flooding of wetlands in the lower Murrumbidgee River. A number of government agencies are responsible for the delivery of these types of environmental water (Figure 18). They include the NSW Office of Water, NSW OEH and SWC as the river operators (although a number of private organisations such as MI are also responsible for water delivery).

Figure 18: Types of environmental water and management roles.



5.2.1.1 Planned environmental water

Planned environmental water includes two categories: rules-based releases (transparent/translucent flows, minimum end-of-system flows) and discretionary water. Planned environmental water varies on a daily basis relative to inflows, catchment 'wetness' and the level of allocation to entitlement holders. In principle, planned environmental water is protected from extraction by downstream users who should only extract water if they hold a licence and have placed an order.

Rules specified in Part 3 of the WSP provide for water to be reserved for the environment, including the protection of low flows and also provision of winter flow variability. Flows below a certain threshold are protected (translucent flows) by rules that provide for releases from Blowering and Burrinjuck Dams. Based on storage inflows, up to 560 megalitres from Blowering Dam and between 300 megalitres and 615 megalitres from Burrinjuck Dam, are to be released daily. The 'rules' provide for a volume of environmental water to accumulate in Environmental Water Accounts (EWAs) when certain conditions are met. Rules also provide for a portion of flows above the threshold to be released as translucent flows and the remainder is stored for consumptive use. Also, a minimum daily flow of at least 300 ML/d is to be maintained in the Murrumbidgee River at Balranald (end-of-system), and 50 ML/d at Darlot in the Yanco Creek system. These contribute to ensuring there is always flow into the Murray River.

There are three tiers of EWAs: EWA1, EWA2 and EWA3. These are managed by NSW OEH on a discretionary basis. The purpose of this environmental water is to maintain and improve in-stream values through enhancing ecological health; specifically by supporting bird breeding, fish recruitment and wetland health. Further details on EWAs are provided in the WSP at Part 3, Clause 15 (8)-(14).

5.2.1.2 Adaptive environmental water

Adaptive environmental water (Clause 16 of Part 2 of the WSP) is a condition placed on a water access licence by the NSW Water Minister. The terms of the condition are to further the objectives of the relevant management plan. Adaptive environmental water is an additional environmental water source, an example of which is water held by the NSW Riverbank program (including purchasing entitlements and donations) (outlined in Section 5.3).

OEH has the core responsibility for this entitlement-based environmental water and the MCMA assists to manage, and report on, the resource condition. Management responsibilities include establishment of the Murrumbidgee Environmental Water Advisory Group (MEWAG); providing advice on environmental water volumes; delivery of environmental water to benefit environmental assets (in-stream, floodplains, wetlands etc.); and resource monitoring, evaluation, reporting and improvement.

Like adaptive environmental water, Commonwealth environmental water is also held water. However, Commonwealth environmental water has the same characteristics as irrigation entitlements and therefore is not subject to the same conditions as adaptive environmental water.

5.2.1 Trading rules and system accounting

The ability to trade between the Murrumbidgee and Murray River systems provides additional opportunities to use allocations accumulated towards the end of the year and to minimise the likelihood of forfeiting carryover provisions due to spills.

The following components from the *Water Sharing Plan for the Murrumbidgee Regulated River* specify rules for the management of water accounts and define the trading arrangement:

- Part 9 (Division 1)—water allocation account management.
- Part 10—access licence dealing rules.
- The WSP provides for licences to be permanently traded by transferring ownership between one licence holder to another, or temporarily traded by transferring the annual allocation (or portion thereof) from one licence holder to another. Water entitlement holders of the Murrumbidgee Valley are able to trade inside and outside of the valley, including with Murray Valley and Lower Darling Valley entitlement holders and inter-state entitlement holders. However, trading rules apply to these transactions and are outlined below. Common rules and temporary trade rules are outlined in Table 17 and trading zones and associated constraints (rules) for permanent and temporary trade are shown in Table 18 and Table 19. Irrigation corporations in the Murrumbidgee Valley also set rules to manage trade within their bulk licences.

Table 17: Common and temporary trade rules in the Murrumbidgee valley. (Adapted from SKM 2008)

Common trade rules	• All allocation assignments (temporary trades) will be for a specified quantity and are dependent upon water being available to the seller. • Domestic and/or stock-access licences and allocations cannot be traded. • Supplementary licences can only be traded from within the same supplementary water-access zone (there are several of these along the Murrumbidgee River). • Supplementary licences cannot be converted to other categories of access licence. Note that holders of supplementary water-access licences are able to extract water only during announced flow events, which are typically when flows exceed those required to meet other licensed obligations and environmental needs (e.g. as a result of high tributary inflows downstream of a dam or when a dam is spilling). • Local water utility access licences (town water supply) may be traded where Council has a Drought Contingency Plan & Demand Management Plan approved by the Department of Energy and Utilities which demonstrates that trade will not affect the security of town water supply. • Trades can occur within the Murray Valley, the Lower Darling Valley and the Murrumbidgee Valley (intra-valley) within supply limitations. • Inter-valley (temporary) trades can occur between Murray, Lower Darling and Murrumbidgee Valley (with restrictions). • Interstate trades can occur between Murray, Lower Darling and the Murrumbidgee Valleys and South Australia or Victoria (with restrictions).
Temporary trade rules	• In the Murrumbidgee Valley, separate applications are required for trading of water available before February 28 and from February 28. • Applications to assign water allocations (high security temporary trade out) must be lodged on the prescribed form with SWC by September 1. • All applications for temporary inter-valley and interstate transfers must be completed on the prescribed form and lodged with SWC by close of business on January 31. • All applications for temporary intra-valley transfers must be completed on the prescribed form and lodged with SWC by close of business on February 28.

Table 18: Permitted licence dealing within permanent zones. (Adapted from SKM 2008)

Selling Matrix	Zone 1	Zone 2	Zone 3	Zone 4	Zone 5	Victoria	South Australia
Zone 1: Murray upstream of the Barmah choke	NR	NR	NA	NA	NA	NP	NP
Zone 2: Murray downstream of the Barmah choke	NP	NR	NA	NA	NA	HSDSN	DSN
Zone 3: Murrumbidgee	NA	NA	NR	NR	NA	NP	NP
Zone 4: Yanco	NA	NA	NP	NR	NP	NP	NP
Zone 5: Lower Darling	NP	NA	NA	NA	NR	NP	NP
Victoria	NP	HSDSN	NP	NP	NP		
South Australia	NP	HSDSN	NP	NP	NP		

Key

NP	Not permitted
NR	No restrictions
NA	Not available
HSDSN	Only HS and D/S Nyah
DSN	D/s Nyah only

Table 19: Permitted licence dealing within temporary zones.

Selling Matrix	Zone 1	Zone 2	Zone 3	Zone 4	Zone 5	Victoria	South Australia
Zone 1: Murray upstream of the Barmah choke	NR	NR	NR	NR	MSL	VCR	NR
Zone 2: Murray downstream of the Barmah choke	MBP	NR	NR	NR	MSL	VLDSC	NP
Zone 3: Murrumbidgee	NTT	NTT	NR	NR	MSL	NTT	NTT
Zone 4: Yanco	NTT	NTT	NR	NR	MSL	NTT	NTT
Zone 5: Lower Darling	NP	MSL	MSL	MSL	NR	MSL	MSL
Victoria		MBP	NR	NR	MSL		
South Australia		MBP	NR	NR	MSL		

Key

NP	Not permitted
NR	No restrictions
NTT	No nett trade into Murrumbidgee
MBP	May be permitted
MSL	Only when Menindee storage above 640 GL
VCR	Subject to Victorian choke rules
VDLSC	Only Victorian licence downstream choke

5.3 Riverbank

The NSW Office of Environment and Heritage (OEH) established Riverbank as an initiative under the *City and Country Environment Restoration Program*, to purchase water rights and manage them to achieve environmental outcomes. The program works within the constraints of the existing water market with purchases only taking place between the agency and willing sellers. Water may be acquired through the purchase of water access licences on behalf of the NSW Government; the purchase of water access licences using funds from other entities such as the Australian Government and local governments and non-government entities (corporations, companies, environmental and not-for-profit organisations (NGOs), and individuals), and via donated water-access licences (OEH 2010). Water may also come from the use and management of water-access licences (for environmental purposes) on behalf of licence holders, and from annual account water donated or sold by licence holders. The OEH has an environmental water management advisory role to state and Australian Governments, catchment management authorities and non-government organisations to optimise the outcomes of watering of environmental assets (OEH 2010).

Riverbank water entitlements are managed to achieve the following objectives (OEH 2010):

- Improving the ecosystem function of wetlands and rivers, including the habitat for aquatic biodiversity.
- Rehabilitating wetland habitat for significant water-dependent biota, including floodplain eucalypts, waterbirds, frogs, reptiles and fish.
- Meeting the nation's international obligations with respect to wetlands and migratory birds.
- Improving water-management decisions to reflect an understanding of the links between environmental and Aboriginal cultural values.

The Riverbank program has specific purposes for acquired water entitlements and often provides water to support other environmental watering actions (OEH 2005). Targeted assets include wetlands on the Lowbidgee floodplain (DIWA listed wetlands complex), predominantly wetlands situated within Yanga National Park.

5.4 The Murray-Darling basin

Work being undertaken by the Murray-Darling Basin Authority (MDBA 2010) follows a number of broad objectives, the following of which are relevant when considering options for the use of environmental water:

- Maintain and improve the ecological health of the basin, and in doing so optimise the social, cultural, and economic wellbeing of basin communities.
- Improve the resilience of key environmental assets, water-dependent ecosystems and biodiversity in the face of threats and risks that may arise in a changing environment.
- Maintain appropriate water quality, including salinity levels, for environmental, social, cultural and economic activity in the basin.

5.5 Summary of roles and responsibilities

Table 20 provides an overview of the roles and responsibilities of government agencies in managing environmental water for Murrumbidgee environmental assets.

Table 20: Agency and irrigation corporation roles in managing environmental water in the Murrumbidgee Valley.

Entity	Role and responsibilities
MDBA	• Development of the environmental watering strategies and plans.
CEW (SEWPaC)	• Preparation of environmental water planning and watering strategies with input from state government and the MDBA. • Operate and deliver Commonwealth environmental water in accordance with the environmental watering plan.
NSW Office of Water	• Implementation of environmental watering strategies and plans • Implementation of the Water-Sharing Plan and preparation of Water Resource Plans when water-sharing plans expire. • Management of planned environmental water.
NSW OEH	• Implementation of environmental watering strategies and plans. • Management of adaptive environmental water and discretionary water. • Riverbank program (acquisition of water licences). • Preparation of Water-Use Plan for the management of adaptive environmental water (statutory document). • Preparation of Annual Environmental Water Plan with input from senior wetlands officers and the Environmental Water Advisory Group.
SWC	• River and dam operator that manages the regulated river on a daily basis. • Delivery along the main river channel and to Lowbidgee and Mid-Murrumbidgee Wetlands, and the Yanco Creek system. • Transmission forfeit along the river channel. • Conduct daily forecasting of tributary contributions to baseflows, and losses, based on the previous day's data.
Irrigation Corporations (MI, Murray Irrigation and Coleambally Irrigation)	• Water delivery • MI—Mirrool Creek floodplain • Coleambally Irrigation—Yanco Creek, Forest Creek, Billabong Creek • Murray Irrigation Limited—Yanco Creek, Forest Creek, Billabong Creek

6. Risk Assessment and Mitigation Strategies

The risk assessment outlined in Table 21 provides an indication of the risks associated with the delivery of environmental water in the Murrumbidgee River catchment. It provides a summary of the risks that have been identified for the river reaches defined in this report. 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. The risks identified in this section require mitigation to optimise the outcomes of delivering environmental water to the assets of the Murrumbidgee River catchment, particularly where risks are high to severe. A framework for assessing risks has been developed by SEWPaC and is included at Appendix H.

6.1 Catchment risks

Drought conditions prevailed across the Murrumbidgee River catchment during most of the period between 2000 and 2010 and resulted in a number of significant impacts including reduced flooding and wetland inundation and reduced habitat availability for threatened flora and fauna and migratory birds. For example, the southern bell frog population significantly declined during this period (Wassens et al. 2008). Environmental watering aims to reduce some of the pressures of drought conditions and mimic more natural watering regimes through watering targeted assets and providing suitable habitat for flora and fauna; however managing flows for this purpose also has inherent risks. These risks can be categorised as follows:

- water quality and salinity risks
- ecological risks
- hydrological risks
- climatic risks
- socio-economic/community/cultural risks.

A number of these categories are interrelated. For example, there is a risk that an environmental watering event may result in flooding which could then affect towns and landholders if inundation occurs. Furthermore, there is a risk that environmental watering which follows prolonged dry periods may result in a blackwater event that could then lead to fish kills. Table 21 provides a summary of the different risks that are associated with environmental watering. Two risks have been deemed to have a high risk rating. These are:

- invasive species introduction (especially in the case of the Mirrool Creek and Yanco Creek systems)
- flooding of properties and infrastructure.

6.2 Mitigation strategies

Options for the mitigation of risks associated with environmental water delivery and use are presented in Table 21. Strategies for alleviating risks include consideration of site-specific issues, such as the frequency and duration of antecedent flows and the current condition of vegetation and soils, to river-wide issues such as control of return flows and salt harvesting, and management options such as the potential for flushing flows, control of return flows, complementary land-management actions, and options for managing the spread of invasive species.

Table 21: Risks associated with water use actions.

Risk Category	Risk	Description	Likelihood	Consequence	Risk level before controls are put in place	Controls
Water quality and salinity	Acid sulphate soils	Limited information is available on acid sulphate soils in the Murrumbidgee catchment. Based upon available information it is assumed that an acid sulphate soil is relatively low risk when not exposed and confined to certain soil-management units. However, where acidification occurs, there is potential for mobilisation of metals which would affect water quality and ecology. Baseline data for soil condition and landholder surveys have identified acid sulphate soils as an issue for the following soil-management units with the Murrumbidgee catchment (OEH 2010): • Cullarin Metasediments. • Murrumbidgee Alluvials. Cullarin Metasediments are generally found around Queanbeyan in the upper-Murrumbidgee catchment, while Murrumbidgee Alluvials are generally found between Wagga Wagga and Griffith and may be an issue for the Mid-Murrumbidgee Wetlands (Figure 19).	Possible	Moderate	Medium	• Provision of flushing flows that would dilute low pH water from inundated wetlands would reduce the risk of acid sulphate soil impacts on water quality and in-stream ecology. • Appropriate wetting and drying cycles alleviate the potential for development of acid sulphate soils. • Avoid the exposure of potential acid sulphate soils.
	Salinity	The reduction in deep-rooted perennials as a result of land-use management practices has resulted in salinity issues for the following soil-management units (Figure 19): • Borree Plains (between Griffith and Hay). • Murrumbidgee Alluvials (between Wagga Wagga and Griffith). These salinity issues are predominantly associated with the groundwater table rising which leads to the concentration of salts within the capillary zone of the soil profile. The concentrated salt has a risk of being exported downstream to wetlands during periods of high flows (e.g. Barren Box Swamp) (Whitten & Bennet 1999). Flood events have the potential to mobilise salt from the floodplain to the Murrumbidgee River and its tributaries. The salt may be mobilised under wetter conditions and increase electrical conductivity. The mobilisation of salts from the floodplain has a positive benefit to the environmental values where salt accumulation has impacted upon the functioning of the ecosystem.	Likely	Moderate	Medium	• Provission of sufficient flows to dilute salts.

Risk Category	Risk	Description	Likelihood	Consequence	Risk level before controls are put in place	Controls
Water quality and salinity	Blackwater	Blackwater events have been recorded with the release of water after prolonged dry or low flow periods resulting from wetting of in-channel leaf litter build-up as well as when floodwaters return to streams following floodplain inundation. Blackwater events, in which water becomes deoxygenated, can result in native fish kills. Blackwater events have been recorded in the Lowbidgee Floodplain area and in Billabong Creek in the Yanco Creek system (D Leslie (Murray CMA) 2010, pers. comm.).	Unlikely to Likely, depending on antecedent conditions	Moderate	Medium	• Monitor watering targets for organic matter accumulation and blackwater risk. • Where appropriate, control return flows to river. • Where appropriate, allocate a contingency allowance for dilution flows. • Provide winter through flows (where possible), to reduce organic matter accumulation in high-risk wetlands.
	Contaminants	Ryder et al. (2007) found that environmental flow releases in the Murrumbidgee River have the potential to mobilise contaminants from surface sediments and biofilms which may affect water quality and impact on in-stream productivity. Results of Ryder et al. (2007) indicate that catchment run-off events that mobilise contaminants stored in biofilms and sediments in tributaries have different chemical characteristics to artificial floods from dam releases. There is also an increased risk of pesticides entering waterways due to the inundation of floodplains used for agriculture.	Possible	Moderate	Medium	• Support improved land management practices and planning. • Land and Water Management Plans.
	Nutrients and algal blooms	Overland flows may be contaminated with fertilisers high in nutrients and can also transport algal blooms that have been isolated in wetlands on the floodplain. Areas particularly susceptible to these impacts are wetlands situated in or adjacent to agricultural districts.	Possible	Moderate	Medium	• Support improved land management practices and planning. • Education programs to better manage the use of fertiliser. • Timing of environmental flows such that larger flows do not exacerbate conditions for algal blooms.
	Erosion and increased turbidity	Base flows in the Murrumbidgee River typically have low turbidity, however, high flows in both the Tumut River and Mirrool Creek have very high levels of turbidity. Increased turbidity results from sheet and gully erosion arising from overland flows and also wind erosion. Sheet and gully erosion is primarily the result of insufficient vegetation cover (OEH 2010).	Possible	Moderate	Medium	• Encourage improved land management practices and planning. • Liaise with the Murrumbidgee CMA and landholders and encourage the management of riparian vegetation.

Risk Category	Risk	Description	Likelihood	Consequence	Risk level before controls are put in place	Controls
Ecology	Spread of weeds	There is potential for the spread of alligator weed (*Alternanthera philoxeroides*) through high flows through the lower Mirrool Creek area. Small patches of alligator weed have been observed in the Wah Wah Irrigation Area. It has also been observed in the wetland cell of Barren Box Swamp. If Barren Box Swamp is involved in the delivery of environmental water there is a risk that alligator weed may spread downstream. Due to the location of alligator weed, there is potential during a large end-of-system flow event to mobilise alligator weed so that it reaches the Lachlan River catchment. Willows *Salix* spp. can reproduce vegetatively (i.e. from roots, twigs or branches deposited in moist soils) enabling willows to germinate in high numbers. Increased flows may increase the densities of willows downstream, as there is a high density of willows in many of the upper wetlands. Aside from alligator weed and willows, increased flows also have the potential to spread a variety of other weeds which have been recorded in the system, including water hyacinth (*Eichhornia crassipes*) and lippia (*Phyla canescens*).	Possible	Major	High	• Avoid using Barren Box Swamp for storage of environmental water. • Inspections and physical removal before environmental water is released. • Use of booms and weed traps to control weeds such as alligator weed. • Willow control measures. • Revegetation programs.
	Invasive species—common carp	Common carp (*Cyprinus carpio*) breeding is likely to be favoured by large flow events. The abundance of common carp larvae and juveniles appears to increase after flooding in wetlands (Stuart & Jones 2006).	Likely	Moderate	Medium	• Common carp control and exclusion methods (such as fishing-down, automated traps, screens and wetland drawdown).
	Rapid water-level decline resulting in fish stranding and unsuccessful waterbird breeding	A rapid fall in water levels can lead to a loss of recruitment of both fish and waterbirds, with potentially significant effects to populations that are already stressed from drought. Too short a duration of inundation of floodplain wetlands may result in a commencement of waterbird breeding and a subsequent abandoning of nests.	Possible	Moderate	Medium	• Monitoring and adaptive management to maintain inundation should large-scale waterbird breeding event commence. • Manage flows to prevent rate of fall from exceeding 15 cm/d. • Transfer environmental water into the Murrumbidgee catchment to meet additional demand.

Risk Category	Risk	Description	Likelihood	Consequence	Risk level before controls are put in place	Controls
Ecology	Prolonged inundation of floodplain vegetation	Vegetation communities that inhabit the floodplain have different watering requirements. Where a floodplain is watered too regularly and for too long, there is potential for dieback as a result of drowning. Extended flooding can also result in anaerobic conditions in the soil for many months. Some wetland plants are adapted to prolonged inundation, however most woody species cannot tolerate flooding for >12 months. Terrestrial plant species with no adaptations to anaerobic soil conditions will not survive even shorter periods.	Possible	Moderate	Medium	• Define the watering requirements of specific wetlands based on vegetation communities. • Where possible, limit floodplain inundation to less than 12 months and allow for drying. • Consider the water level that is required to water inundation-dependent vegetation for targeted wetlands. • Apply precautionary principles to reduce the incidence of prolonged inundation.
Hydrology	Water loss	Some landholders can access water releases particularly in the irrigation districts such as Mirrool Creek and must therefore be made aware of environmental watering events so that this water is not unintentionally diverted.	Possible	Moderate	Medium	• Inform landholders of timing of the release. • Work with NSW Office of Water to establish arrangements to improve the security of environmental water.
	Inappropriate watering regime	Further study is needed to determine optimal duration and interval length between inundation events to maximise fauna and flora responses in key wetlands in the Murrumbidgee River system.	Possible	Moderate	Medium	• Further research into potential impacts of sub-optimal inundation regimes of key fauna and flora species, such as the Southern bell frog. • Adaptive management to achieve intended watering outcomes.
	Flow Interruption	Unforeseen physical impediments to flow delivery may hamper the efficiency of water delivery. For example, Cumbungi *Typha* spp. may form dense stands in irrigation channels, slowing the delivery of water and requiring greater volumes to reach target sites.	Possible	Moderate	Medium	• Early communication with landholders, and SWC. • Policies in place if illegal obstructions are identified. • Impediments to flow will be managed on a case-by-case basis, as they are likely to be different each time.

Risk Category	Risk	Description	Likelihood	Consequence	Risk level before controls are put in place	Controls
	Inundation of land and infrastructure	Increased potential for inundation and isolation of properties that utilise the lower floodplain particularly for agricultural activities and general property access—such as apple and pear trees in lower Gundagai and Wagga Wagga districts.	Possible	Major	High	• Adhere to flow thresholds so that inappropriate inundation does not occur. • Adhere to the delivery constraints in the WSP 2003 and SWC Water Supply Work Approval. • Keep the community informed of environmental watering actions. Engage local councils to assist with this process. • Implement an information campaign and rapid effective response efforts should these risks eventuate to minimise any damage.
Climate	Climatic variability	The climate of the Murrumbidgee catchment is highly variable, which means that baseflows in the river can be highly variable and somewhat unpredictable. Climate change is likely to result in more frequent extreme weather conditions, including drought events, resulting in less water being available than expected.	Possible	Major	Medium	• Review asset conditions and future priorities. • Watering options to be modelled around best available models and historic data which have been informed by best available climate change scenarios including very wet scenarios.
Socio-economic, community & culture	Damage to forestry	There is also forestry of river red gums and cyprus pines *Pinus radiata* on the Murrumbidgee floodplain. Increased flows and inundation periods may impact upon these forestry activities (Whitten & Bennet 1999).	Possible	Moderate	Medium	• Adhere to flow thresholds so that flooding of forestry areas does not occur. • Maintain up-to-date land use maps so that land used for this purpose is well documented.
	Inundation of cultural heritage sites	Campsites and shell middens are found along the Murrumbidgee River and lower Mirrool Creek (MCMC 1998; Grose & Makewita 1997 in Whitten & Bennett 1999). Canoe and shield trees are found in many locations along the Murrumbidgee River in addition to rarer, high-value sites, such as 'birthing trees' and ceremonial grounds (Whitten & Bennett 1999). There is potential for these sites to be impacted by high river flows.	Possible	Minor	Low	• Artefacts along the Murrumbidgee and Lower Mirrool Creek would traditionally have been inundated during natural flooding regimes. • Inform appropriate stakeholders if additional sites are identified.

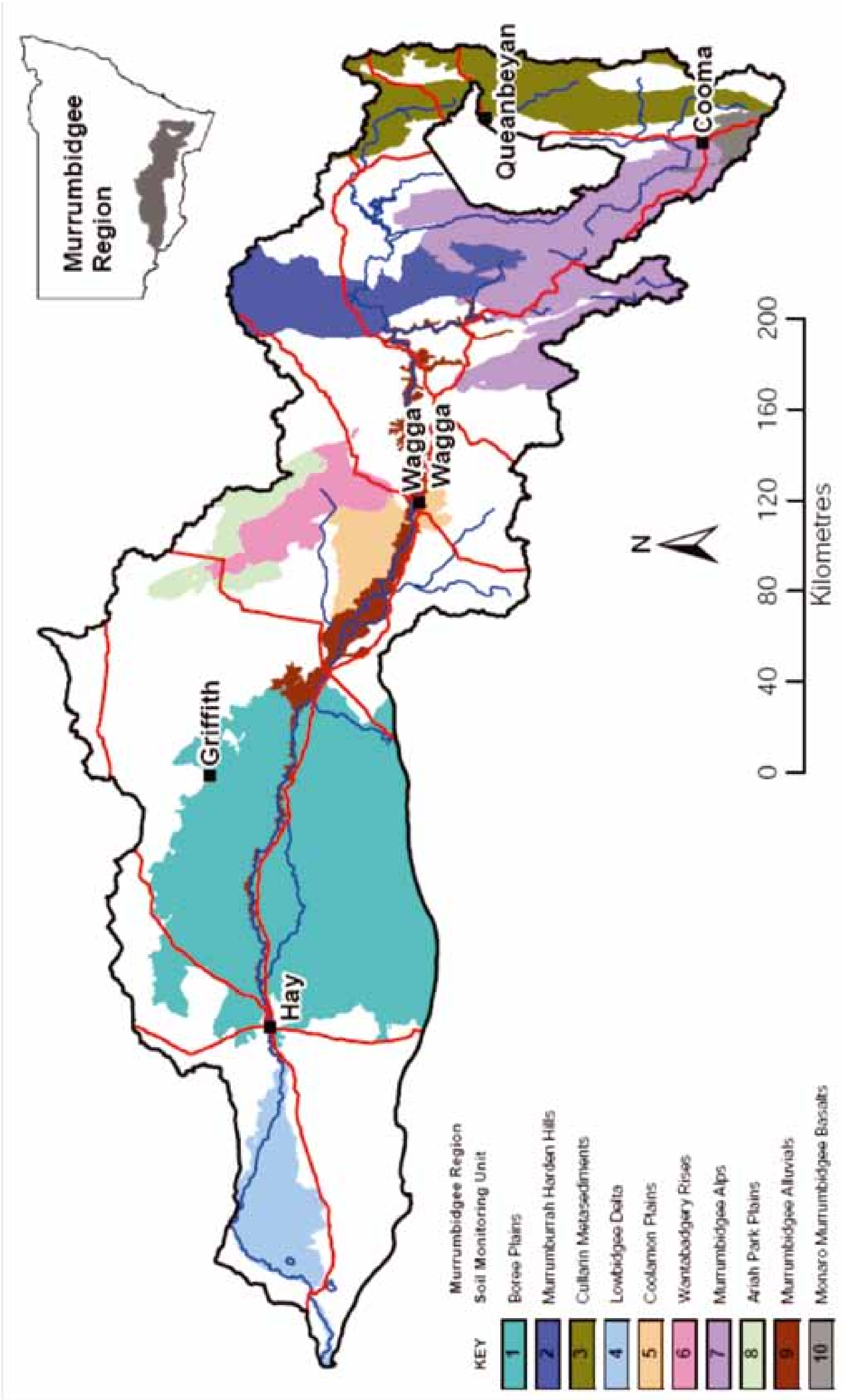


Figure 19: Soil management units for the Murrumbidgee catchment. (Source: OEH 2010b)

7. Environmental Water Reserves

7.1 Environmental water holdings

Two categories of environmental water exist in the *Water Sharing Plan for the Murrumbidgee Regulated River Water Source 2004*—planned environmental water (rules-based) and adaptive environmental water:

- Rules-based – these flows include those that pass through dams more or less continuously in the form of transparent and translucent flows, where the volume of release is subject to factors such as dam inflows. Where certain conditions are met, the rules also provide for a volume of environmental water to accumulate as Environmental Water Allowances (EWAs). This water can be used in a discretionary manner, with releases timed and configured to suit environmental objectives such as watering wetlands to support bird-breeding events. The use of this water is managed by OEH, with advice from the Murrumbidgee EWAG.
- Adaptive Environmental Water – Adaptive environmental water can be acquired through a number of sources, including water-recovery programs that purchase water access licences. They include the NSW Riverbank Program, Rivers Environmental Restoration Program, NSW Wetlands Recovery Program and The Living Murray Market Purchase Measure (for Murray River use). These programs have helped to recover 64,534 megalitres of general security and 5,679 megalitres of supplementary access shares as at 30 June 2010 (NWC 2010). They are managed by NSW OEH, with advice from the Murrumbidgee EWAG.

Any water access licence can be used for environmental purposes and is not limited to adaptive environmental water licences (NWC 2010). Adaptive environmental water which is allocated cannot be used for any other purpose than that which results in environmental benefit. Further details regarding the governance arrangements for adaptive environmental water and EWA water are provided in Section 4.10.

Commonwealth environmental water holdings are an example of water-access licences used for environmental purposes that are not subject to adaptive environmental water conditions. The Australian Government is acquiring environmental water through various water savings schemes and through purchases of entitlements. These entitlements are managed by the CEWH and are subject to the same fees, charges and conditions as other entitlement holders.

7.2 Water availability

Water availability varies from year to year and also seasonally, depending on climate conditions. Recognising that there are some high priority users, the Water Sharing Plan provides a hierarchy of supply. The requirements of 'basic landholder rights', 'domestic and stock' and 'local utility licences' must be met before other entitlements are provided a share of available water. High-security entitlements are next in the hierarchy and must achieve an allocation of 0.95 of a megalitre/share before any allocations are granted to general-security entitlements.

The amount of water available for high security and general-security licence holders (Available Water Determination (AWD), or alternatively 'Allocation') is computed progressively throughout the year, taking into account storage volumes held in the dams and expected inflows (typically by adding the lowest historical inflows for the remaining period of the year to existing storage volumes).

The NSW Office of Water provides regular updates on water availability for the Murrumbidgee Valley.

The NSW government manages environmental water allowances according to the *Water Sharing Plan for the Murrumbidgee Regulated River Water Source 2003* (NSW). The Water Sharing Plan includes provisions for environmental water according to a complex set of 'rules', for which there are no specific entitlements. These rules allow for releases of EWA when certain conditions are met, to be used in a discretionary way to enhance ecological health. The three types of EWA are established and managed according to the following:

- EWA1 is accrued when the available water determination for general security licences (plus carryover from the previous year of general security licences) achieves 0.6 of a megalitre/share, up to a maximum amount of 50,000 megalitres. Under certain conditions additional water up to a limit of a further 50,000 megalitres may be accrued to the EWA1 volume. EWA1 water not used in a given year can be carried over into the following year, up to a maximum amount of 50,000 megalitres. Additional EWA volumes are accrued as EWA2 and EWA3 depending on the general availability of water in the dam catchments.
- EWA2 is accrued when transparent or translucent releases are made from Burrinjuck Dam, a volume up to 315 ML/d is credited to the account depending on the size of the transparent/translucent release.
- EWA3 is accrued when general-security licence determinations and carryover from the previous year exceed 0.8 of a megalitre for every general-security licence share, a proportion of this volume can be credited to EWA3 between July 1 and January 1.

7.2.1.1 Environmental water register

Details of held environmental water (adaptive environmental water licences) are included in the NSW Environmental Water Register managed by NOW. The following details are included on the register:

- Water access licences that are dedicated as a source of adaptive environmental water (AEW).
- Environmental water set aside in accordance with rules in the Water Sharing Plans.
- Adaptive Environmental Water Use Plans that are endorsed by the minister.

7.2.1 Commonwealth environmental water holdings

The role of the Commonwealth environmental water holder (CEWH) was established by the *Water Act 2007* (Commonwealth). The CEWH is responsible for the management of held Commonwealth environmental water entitlements.

7.2.1.1 Register of water holdings

Details of Commonwealth environmental water holdings are maintained in a register which is managed by the Australian Government. This register provides details of the entitlements held and water available for use at any given time; this information is publicly available at: http://www.environment.gov.au/ewater/about/holdings.html. The Commonwealth environmental water holdings for the Murrumbidgee catchment as at 4 October 2011 are listed in Table 22. Note: water can be traded, depending on environmental demand, into or out of other areas of the southern connected basin, or traded out of the Murrumbidgee River catchment.

Table 22: Commonwealth environmental water holdings as at 4 October 2011.

Category	Shares*	Dependencies
High Security	429	Dependent on allocation and other priorities in the southern connected Murray system.
General Security	118,568	Dependent on allocation and other priorities in the southern connected Murray system.
Supplementary	20,820	Dependent on access announcements. Note: only able to be used in the Murrumbidgee River catchment^.

** Under current arrangements 1 share is equivalent to 1 ML at full allocation. This can be subject to revision if there is indication of a growth in use.*

^ The current Water Sharing Plan does not allow trading of Supplementary shares out of the Murrumbidgee River catchment, however, there is potential to negotiate (e.g. under a Memorandum of Understanding with the NSW Office of Water) for Supplementary shares to be shepherded through the Murrumbidgee River system.

7.3 Seasonal variations in available water determination

Available Water Determinations (AWDs) vary between years and also throughout a year. They typically start low at the beginning of the year and increase throughout the year, reaching a maximum around March. The optimal time for environmental watering tends to be spring, when allocations are typically low. There have been some years with zero allocation, but the end-of-year allocation is typically between 60 to 100 per cent.

7.3.1 Use of supplementary flows

Supplementary entitlements give users the right to divert flows during declared supplementary flow events. Any extraction that occurs reduces the magnitude of these high-flow events downstream. Since high-flow events provide an environmental service by inundating the wetlands with higher commence-to-fill rates, especially in the Mid-Murrumbidgee, it is generally recommended that significant supplementary flows should not be extracted for environmental purposes in the upper or mid-Murrumbidgee reaches. It is therefore recommended that supplementary access entitlements be used for water assets in the Lowbidgee.

The Lowbidgee is currently not included in the Murrumbidgee Regulated River Water Sharing Plan, however the plan is currently being amended to include the Lowbidgee. The current plan does include the provision for diversion of supplementary flows (known as Lowbidgee Access flows) into the Lowbidgee. These flows can only be applied to watering assets in the Lowbidgee.

7.3.2 Flow characteristics

Flow patterns under different climate conditions are presented for Wagga Wagga, Narrandera, and Maude in Table 23, Table 24 and Table 25. This information was sourced from the Murrumbidgee IQQM model (provided by the NSW Office of Water) for current operating conditions using modelled data from the period 1892 to 2010. Data was sorted according to day of the year (i.e. 0 to 365). Flows for each day within each month were then ranked from lowest to highest, and the various percentiles derived.

Even in the most severe drought, the Murrumbidgee River maintains flow all year around, although monthly flows are typically less than 20 per cent of those in a wet year. There is a strong seasonal trend in flows, although seasonality varies with location. In the upper sections of the river, such as at Wagga Wagga, the highest flows occur in October, November, December and February (late spring and summer) as a result of releases for irrigation. In the mid-sections at Narrandera the highest flows occur from October to February due to irrigation demand, while in the lower sections of the river, such as Maude, flows return to a more natural seasonal pattern (as this area is downstream of the main irrigation areas) and the highest flows occur in July, August and September (late winter/early spring).

Table 23: Streamflows (ML/d) for the Murrumbidgee River at Wagga Wagga (1892 to 2010).

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)
July	1,535	4,344	8,151	13,211
August	2,209	6,666	11,740	17,751
September	4,031	9,774	13,291	16,128
October	4,803	12,288	14,239	16,136
November	4,711	10,259	11,943	13,970
December	3,079	12,016	14,044	14,928
January	2,947	12,734	14,174	15,570
February	3,916	9,650	10,952	12,143
March	2,746	7,145	8,108	8,933
April	997	4,526	5,577	6,289
May	1,178	2,100	2,725	4,963
June	1,170	2,882	5,226	9,652

Table 24: Streamflows (ML/d) for the Murrumbidgee River at Narrandera (1892 to 2010).

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)
July	1,479	4,144	7,463	12,630
August	1,436	5,061	10,224	16,411
September	2,326	6,464	11,631	15,752
October	3,031	7,376	9,016	11,166
November	2,948	6,238	7,809	9,522
December	2,002	7,083	8,738	9,601
January	1,284	7,917	8,975	9,660
February	1,498	5,968	6,829	7,922
March	1,817	4,118	4,675	5,155
April	424	2,831	3,425	3,998
May	949	1,580	2,090	4,686
June	1,161	2,705	4,760	8,466

Table 25: Streamflows (ML/d) for the Murrumbidgee River at Maude (1892 to 2010).

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)
July	806	2,193	3,574	7,123
August	1,086	2,579	5,714	10,585
September	1,567	2,621	6,163	11,598
October	1,416	1,543	3,305	5,463
November	1,053	1,191	1,341	3,298
December	483	730	771	1,126
January	479	544	577	728
February	308	545	574	621
March	713	811	853	917
April	489	871	892	956
May	263	447	481	1,795
June	481	765	1,355	3,665

8. Water Delivery Costs

In the Murrumbidgee catchment the principle water infrastructure operators are SWC, MI and CICL. These organisations operate a variety of irrigation infrastructure across the catchment, which are also used for the delivery of environmental water. Private landholders may also permit the canals and channels on their properties to be used for the delivery of environmental water.

Ideally, the most cost-effective means of water delivery should be adopted, particularly from an operational perspective, but this is not always feasible or conducive to achieving optimal environmental outcomes. In terms of water-delivery costs, a number of factors must be considered in the delivery of environmental water:

- the different delivery paths and ownership of infrastructure
- timing of releases (i.e. does the watering action coincide with delivery of water for landholders?)
- system capacity
- delivery mechanisms (i.e. gravity fed or pumping?).

The following sections provide an overview of water-charge arrangements relevant to the delivery of environmental water in the Murrumbidgee River catchment.

8.1 Water-charge arrangements

8.1.1 State Water Corporation

As the entity responsible for the delivery of bulk water in the regulated river systems of NSW, State Water Corporation (SWC) recovers its operational costs through water charges. The level of water charge depends upon a number of factors including the type of licence (general or high security), the catchment and the volume.

The Independent Pricing and Regulatory Tribunal (IPART) determines the price structure for water delivery, with cost reviews considering water availability and costs associated with maintenance and upgrade of water infrastructure owned and operated by SWC. IPART Determination No. 2 specifies the 2011–12 (effective 1 July 2011) regulated river prices that apply to water delivered by SWC in the Murrumbidgee Valley (Table 26). Note that an additional levy applies for the Yanco/Colombo system (an extra $0.90 per megalitre/unit share of entitlement).

Table 26: River water prices for 2011–12.

Category	Cost ($/ML)	
	SWC	NSW Office of Water
High security	$2.69	$1.08
General security	$1.60	$1.08
Usage cost	$3.70	$0.69

Note: IPART is currently considering charges, with 2010 determinations continuing in the interim.

Delivery of environmental water incurs usage costs of $4.39 per megalitre, with SWC absorbing the cost of transmission loss along its network of regulated rivers. This price is valid for 2011–12 and includes the $3.70 per megalitre paid to SWC and $0.69 per megalitre paid to NOW. This charge is the same as other water users. High and general-security costs are applied to the entitlement holdings separately to the use costs.

8.1.2 Murrumbidgee Irrigation Limited

The MI supply network is situated to the north of the Murrumbidgee River between Narrandera and Booligal and includes Barren Box Swamp located in the Mirrool Creek floodplain. The 2010–2011 schedule of charges includes different charges for general and high-security entitlements. Annual fixed charges per megalitre are listed in Table 27 and include licence and conveyance charges.

Table 27: 2011–12 annual fixed charges for bulk water delivery via the MI supply network.

Category	Licence ($/ML)	Conveyance cost ($/ML)
High security	$3.77	$0.29
General security	$2.68	$0.29

Note: Costs information sourced from MI (2011). These costs apply to members. Costs are indicative and are likely to be negotiable on an event-by-event basis.

8.1.3 Coleambally Irrigation Cooperative Limited

The Coleambally Irrigation supply network is situated to the east of Hay and is capable of diverting water from Murrumbidgee River into Yanco Creek and Billabong Creek. These creeks form part of the Edward-Wakool system which terminates at the Murray River. Coleambally Irrigation has previously worked with State Water to deliver water to Yanco Creek and to Billabong Creek through their irrigation supply network. These events and the charges for them have been arranged on an *ad hoc* basis, with the charges often being agreed after the event has occurred (A Tiwari (CICL) 2011, pers.comm., 9 August). However, Coleambally Irrigation is currently in negotiation with State Water to formalise costs to use the Coleambally Irrigation supply network.

8.1.4 Private landholders

There are currently no formal delivery cost arrangements in place where OEH is delivering water to an environmental asset on private land. Generally, OEH contacts the landholder to seek permission to use their infrastructure, generally, private irrigation channels or pumps.

A number of factors must be considered including whether the watering action will coincide with the delivery of irrigation water as channel capacity will be reduced if both irrigation water and environmental water are delivered at once. This can result in spills and reduce the amount of water that reaches the intended environmental assets.

The cost to use private infrastructure has been agreed informally at this stage and is as follows:

- use of private networks nearby Maude such as the Nimmie-Caira incurs a cost of $1 per megalitre.
- pumping costs vary across the system from $15 per megalitre to $50 per megalitre depending on the pump type and location.

9. Monitoring, Evaluation and Improvement

Monitoring and evaluation are essential components of any management action, contributing to determining its effectiveness and improvements for future planning. By evaluating the outcomes of environmental flows through routine and/or event-based monitoring, environmental water managers will be able to adapt watering actions to optimise environmental benefits and inform future water-use planning.

A robust approach to monitoring and evaluation is critical to determining the long-term outcomes of the use of environmental water, and to provide information to support good governance and adaptive management.

9.1 Existing monitoring programs and frameworks

A number of existing programs are relevant to assessing the effectiveness of environmental flows in the Murrumbidgee River catchment. The key programs are:

- the Integrated Monitoring of Environmental Flows (IMEF) program, managed by the NSW Office of Water
- the Rivers Environmental Restoration Program (RERP), managed by NSW OEH
- the Riverbank Monitoring Plan for adaptive environmental water
- Sustainable Rivers Audit
- and event-based monitoring.

Key ecological indicators previously monitored in the Murrumbidgee River catchment include:

- macro invertebrates (including abundance, richness and diversity of mayfly larvae, gastropods and shrimp) (King et al. 2003)
- biofilms (including total, algal and organic biomass) (King et al. 2003)
- riparian vegetation (including diversity, distribution, abundance, survival and growth rates) (King et al. 2003)
- condition of floodplain trees (including chlorophyll fluorescence) (King et al. 2003)
- frog community abundance, species richness and diversity
- phytoplankton (including density of cyanobacteria).

Further details regarding these monitoring programs are provided in Table 28.

Table 28: Existing monitoring programs in the Murrumbidgee River catchment.

Program/Agency	Description	Parameters	Sites in the Murrumbidgee
IMEF Office of Water	The IMEF program was established to monitor the ecological benefits provided by environmental flows (Hone et al. 2010). It aimed to protect or restore flow levels and variability to natural ranges. Data collected for the Murrumbidgee was used to analyse the effects of water flow on riparian habitat downstream of Burrinjuck Dam and in the larger billabongs of the Murrumbidgee Floodplain. A number of flow scenarios were modelled to compare ecological benefits. Generally, most ecological improvements resulted from the combined effects of operational changes and increased flow allocated. However, habitat index for Murray cod at Gundagai and Redbank as well as overall river condition index showed improvements only with increased environmental water allocations.	IMEF involved monitoring of hydrology, phytoplankton, biofilms, terrestrial organic matter imputers, river fish and plants, macro invertebrates, birds, amphibians and water quality of wetlands. (Maguire & Simpson 2010, King et al. 2003)	IMEF monitoring has included wetland vegetation at Berry Jerry Lagoon, and Narrandera Forest Lagoon, and fish surveys in the Yarradda Lagoon complex downstream of Redbank Weir (Watts et al. 2003).
RERP OEH (Commonwealth co-funded)	RERP is an environmental watering program comprising of four sub-programs: 1. Acquisition and management of environmental water. 2. Better use of environmental water. 3. Better delivery of environmental water. 4. Partnerships for the management of environmental water on private land (Hyne & Mann 2009). Of particular importance is sub-program 2 which aims to develop a greater understanding of the water requirements of key flora and fauna and to monitor the outcomes of environmental watering in the Lowbidgee Wetlands.	Monitoring of the Lowbidgee Wetlands included the development of hydrodynamic and hydrological models for the Lowbidgee, inundation and vegetation mapping, soil surveys, surveys of waterbirds, frogs, fish and invertebrates (Hyne & Mann 2009). This has led to the identification of key Lowbidgee and Yanga wetlands and the desired watering regimes for the maintenance of the southern bell frog (Hyne & Mann 2009).	Lowbidgee Floodplain
Riverbank Monitoring Plan	The Riverbank Program facilitates the purchase and management of water for the environment. The water portfolio from buying water-access licences is managed to achieve environmental benefits. Monitoring and evaluation of the effectiveness of the Riverbank program involves measuring and accounting for the delivery of water to ecological targets and determining ecological outcomes.	A monitoring, evaluation and reporting strategy is being developed for the Riverbank program. A new state-wide monitoring, evaluation and reporting framework will be adopted to align with environmental watering strategies and plans.	

Program/Agency	Description	Parameters	Sites in the Murrumbidgee
Event-based monitoring OEH	*Watering of Lowbidgee Wetlands (2007–08)* The Lowbidgee Floodplain received environmental water between December 2007 and March 2008 in response to a lack of flooding and drying of key wetlands formally occupied by the southern bell frog (*Litoria raniformis*) (Wassens et al. 2008).	Frog community abundance, diversity and species richness. Physicochemical parameters.	Monitoring sites and approximate date watered: • Avalon Swamp (3/01/08) • Eulimbah Swamp (12/12/07) • Warwaegae Dam (20/12/07) • Mercedes swamp (14/12/07) • Pocock's swamp (21/12/07) • Two Bridges Swamp (03/01/08) • Redbank Weir pool (control site) Incidental sites: • Shaw's swamp (06/01/08) • Torry Plain Stock Dam (15/03/08) • Telephone Bank (6/01/08) • Loorica Rd Burrow pit (01/01/08) • Paul Coates Swamp (Redbank Weir) (10/01/08)
	There have been studies undertaken that have looked at filling options for wetlands in the MIA. Monitoring was undertaken by applying IMEF methods, for assessing the wetland condition from filling, key parameters monitored include water, soil, fringing vegetation and aquatic vegetation.	IMEF parameters	Wetlands in the MIA
	Environmental watering in 2008 to 2010 Spencer and Wassens (2009, 2010) undertook monitoring following environmental watering on the Lowbidgee Floodplain.	Vegetation (aquatic and fringing habitat) Water quality (turbidity, conductivity, temperature, dissolved oxygen and water depth) Fish community abundance, diversity and species richness. Waterbird community abundance, diversity and species richness. Frog community abundance, diversity and species richness. Note: Not all parameters were monitored at all sites.	Sites on the Lowbidgee Floodplain including: • South Eulimbah • Telephone Creek • Wagourah Lagoon • Paul Coates Swamp and Redbank Canal • Mercedes Swamp • Two Bridges Swamp • Monkem Creek • Avalon Swamp • Warwaegae Swamp/Dam • 1AS Regulator Channel North Redbank Canal (fish only)

9.2 Operational water delivery monitoring

Water delivery in the Murrumbidgee River catchment is currently monitored using gauges located along the river at major weirs and block banks. This data is often complemented by observations at specific field-monitoring locations along the river (as per the field sampling regimes described in Table 28). In terms of monitoring specific managed environmental flows events, the Commonwealth environmental watering program requests collection of data on the following parameters using a standardised proforma:

- site name
- site location
- contact person for the watering event
- event details (watering objectives, volume of water allocated, details of water delivered and delivery measurement, details of any differences in agreed and actual delivery volumes, area inundated by the event duration of inundation)
- risk management and monitoring data (e.g. water-quality issues)
- other issues
- observations
- photographs of site pre-delivery, during delivery and post-delivery.

A copy of the Operational monitoring proforma is provided at Appendix G.

9.3 Key parameters for monitoring and evaluating ecosystem response

Choice of response variables in any ecological study should be based on a range of criteria, from logistical and technical points, to issues concerning the specific ecological or taxonomic objectives. The key monitoring aim of the present study, to determine ecological responses to environmental flows in the Murrumbidgee River catchment, means that parameters need to be capable of demonstrating responses at the temporal scale of individual flow pulses and at a range of spatial scales.

The range of suggested biotic variables and parameters for use in the Murrumbidgee River catchment is summarised in Table 29. Each variable is suitable for determining the response to ecological flows to meet most of the ecological objectives presented in Section 3 (ecosystem resilience is the exception). In isolation, the variables in Table 29 will not provide data relating to maintaining and improving ecosystem resilience. However, when considered in combination, they will provide sufficient data describing local and landscape changes that will allow insight into apparent and potential changes in patterns and processes in the river system, and hence ecosystem resilience.

Table 29: Potential biotic variables and parameters for monitoring ecological response to environmental flows. (Adapted from Wilson et al. 2009)

Parameter*	Ecological Objective	Monitoring Method	Rationale	Responsibility
Water chemistry	• Maintain water quality in channels, pools and wetlands. • Prevent stratification in deep pools.	• Salinity • pH • Dissolved oxygen • Temperature • Turbidity • Conductivity • Suspended solids • Dissolved organic carbon • Phosphorus and nitrogen	• Provides data on physicochemical responses to environmental flows and also assessment acid sulphate chemical response. • Sampling and analytical methods are well established. • Some data is likely available from previous monitoring conducted in the catchment.	• NOW manages current instantaneous salinity, dissolved oxygen, turbidity, pH and temperature monitoring at a number of gauging stations in the system.
Algae	• Maintain water quality in channels, pools and wetlands. • Prevent stratification in deep pools.	• Chlorophyll a • Diatom cell abundance and taxonomic composition • Pelagic cell abundance and taxonomic composition • Benthic algal biomass and taxonomic composition	• Base of aquatic food webs. • Exhibit relatively rapid responses to flow variability. • High public awareness.	• NOW manages an algal monitoring program that provides counts of blue-green algae.
Macrophytes	• Maintain and improve semi-permanent aquatic vegetation communities to good condition.	• Shoot density • Taxonomic composition • Seedbank germination	• Macrophytes are a key structural component of aquatic ecosystems. • Potential rapid response to flow variability.	• NOW and OEH monitor the condition of selected wetlands throughout the system.
Floodplain vegetation	• Maintain and improve river red gum forest/woodland, black box woodland and lignum communities.	• Species composition, abundance and biomass • Seedbank emergence	• Key structural component of floodplain ecosystems. • High public awareness. • Management focus. • Potential availability of historic data sets and long-term monitoring sites. • Relatively rapid response to overbank flows.	• NOW and OEH monitor the condition of selected wetlands throughout the system. • MI monitors vegetation rehabilitation in Barren Box Swamp.

Parameter*	Ecological Objective	Monitoring Method	Rationale	Responsibility
Amphibians	• Maintain southern bell frog breeding sites in good condition, and support breeding events.	• Abundance and taxonomic composition • Spawning activity	• Public awareness. • Relatively rapid response to flow variability.	• OEH monitors frog populations at selected sites throughout the system, especially southern bell frog sites in the Lowbidgee.
Fish	• Maintain water quality in channels, pools and wetlands. • Prevent stratification in deep pools. • Maintain and improve longitudinal and lateral connectivity.	• Abundance and taxonomic composition • Spawning activity • Size structure	• Public awareness. • Minimal laboratory effort required, apart from otolith analyses of spawning timing. • Potentially rapid response to flow variability in spawning activity.	• OEH monitors fish populations at selected sites throughout the system. • NSW Fisheries previously sampled fish communities throughout the Murrumbidgee River catchment (Gilligan 2005).
Waterbirds	• Maintain known colonial waterbird breeding sites in good condition, and support breeding events.	• Abundance and taxonomic composition • Fledgling success	• Public awareness. • Relatively rapid response to flow variability.	• OEH monitors waterbird populations at selected sites throughout the system, especially rookeries in the Lowbidgee. • Waterbird populations at Tuckerbil and Fivebough Swamps are monitored by the Fivebough and Tuckerbil Wetlands Trust.
Hydrologic connectivity	• Flows are delivered in a timely and effective manner. • Maintain and improve longitudinal and lateral connectivity to protect and restore the endangered ecological community, including threatened species.	• Water level and timing, magnitude and flow frequency • Inundation area mapping	• Hydrological connectivity is important for transport of sediments, nutrients and energy and also the river channels and wetland connectivity. Hydrological connectivity is also an important vector for movement of aquatic biota and contributes to ecosystem resilience.	• NOW manages current instantaneous level and discharge at a number of gauging stations in the system.

** Any monitoring undertaken should be checked for consistency with MDBA and Australian Government water strategies and plans*

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Appendix A
Murrumbidgee catchment LGAs

Balranald	Junee
Bega Valley	Leeton
Bland	Lockhart
Boorowa	Murrumbidgee
Carrathool	Narrandera
Conargo	Palerang
Coolamon	Queanbeyan
Cooma-Monaro	Snowy River
Cootamundra	Temora
Eurobodalla	Tumbarumba
Goulburn Mulwaree	Tumut Shire
Greater Hume Shire	Upper Lachlan
Griffith	Urana
Gundagai	Wagga Wagga
Harden	Wakool
Hay	Yass Valley
Jerilderie	Young

Appendix B
Threatened species in the Murrumbidgee

Common name	Scientific name	EPBC Act	CAMBA	JAMBA	ROKAMBA	IUCN Red list	TSC Act	Lowbidgee	MIA	Murrumbidgee River (Gundagai to Maude)	Murrumbidgee River (Balranald to Murray River junction)	Yanco Creek System
Birds												
Australian pratincole	*Stiltia isabella*	M							x			
Australasian bittern	*Botaurus poiciloptilus*					*	V	x	x	x	x	x
Australian bustard	*Ardeotis australis*						E		x	x	x	
Australian painted snipe	*Rostratula australis*	V	*				E	x	x		x	x
Barking owl	*Ninox connivens*						V	x	x	x	x	
Bar-tailed godwit	*Limosa lapponica*	M							x			
Black-breasted buzzard	*Hamirostra melanosternon*						V		x	x	x	
Black-chinned honeyeater (eastern subspecies)	*Melithreptus gularis gularis*						V		x	x		
Black-necked stork	*Ephippiorhynchus asiaticus*						E		x			
Black-tailed godwit	*Limosa limosa*	M	*	*	*		V	x	x	x		
Black-winged stilt	*Himantopus himantopus*	M							x			
Blue billed duck	*Oxyura australis*					*	V	x	x	x	x	x
Brolga	*Grus rubicunda*						V		x	x		x
Brown treecreeper	*Climacteris picumnus*						V	x	x	x	x	x

Common name	Scientific name	EPBC Act	CAMBA	JAMBA	ROKAMBA	IUCN Red list	TSC Act	Lowbidgee	MIA	Murrumbidgee River (Gundagai to Maude)	Murrumbidgee River (Balranald to Murray River junction)	Yanco Creek System
White browed treecreeper (population in Carrathool LGA south of the Lachlan River and Griffith)	*Climacteris affinis*						End. Pop.					
Bush stone curlew	*Burhinus grallarius*	E				*	E		x	x		x
Caspian tern	*Sterna caspia*	M	*	*				x				
Cattle egret	*Ardea ibis*	M	*	*				x	x		x	x
Chestnut quail-thrush	*Cinclosoma castanotus*						V	x	x	x	x	
Common greenshank	*Tringa nebularia*	M	*	*	*			x				
Curlew sandpiper	*Calidris ferruginea*	M	*	*	*			x	x			
Diamond firetail	*Stagonopleura guttata*					*	V		x	x		x
Double-banded plover	*Charadrius bicinctus*	M							x			
Eastern curlew	*Numenius madagascariensis*	M	*	*	*			x				
Flame robin	*Petroica pheonicea*						V		x	x		x
Fork-tailed swift	*Apus pacificus*	M	*	*	*			x			x	x
Freckled duck	*Stictonetta naevosa*						V	x	x	x	x	
Gang-gang cockatoo	*Callocephalon fimbriatum*						V			x		
Gilbert's whistler	*Pachycephala inornata*						V	x	x	x	x	
Glossy black-cockatoo	*Calyptorhynchus lathami*	End. Pop.					V		x	x		

Common name	Scientific name	EPBC Act	CAMBA	JAMBA	ROKAMBA	IUCN Red list	TSC Act	Lowbidgee	MIA	Murrumbidgee River (Gundagai to Maude)	Murrumbidgee River (Balranald to Murray River junction)	Yanco Creek System
Glossy black-cockatoo (Riverina population)	*Calyptorhynchus lathami*						End. Pop.	x	x	x	x	x
Glossy ibis	*Plegadis falcinellus*	M	*					x				
Great egret, white egret	*Ardea alba*	M	*	*				x	x		x	x
Great knot	*Calidris tenurostris*	M							x			
Grey falcon	*Falco hypoleucos*						V		x	x		
Grey-crowned babbler (eastern subspecies)	*Pomatostomus temporalis temporalis*						V	x	x	x	x	x
Hooded robin (south-eastern form)	*Melanodryas cucullata cucullata*						V	x	x	x	x	
Lathams snipe	*Gallinago harwickii*	M	*	*	*			x	x		x	x
Little eagle	*Hieraaetus morphnoides*						V	x	x	x	x	x
Little lorikeet	*Glossopsitta pusilla*						V			x		
Long-toed stint	*Calidris subminuta*	M							x			
Magpie goose	*Anseranas semipalmata*						V		x	x		
Major mitchell's cockatoo	*Cacatua leadbeateri*						V	x	x	x	x	
Malleefowl	*Leipoa ocellata*	V					E	x	x	x	x	
Marsh sandpiper	*Tringa stagnatilis*	M	*	*	*			x	x			
Masked owl	*Tyto novaehollandiae*						V	x	x	x		x
Night parrot	*Pezoporus occidentalis*						E		x			

Common name	Scientific name	EPBC Act	CAMBA	JAMBA	ROKAMBA	IUCN Red list	TSC Act	Lowbidgee	MIA	Murrumbidgee River (Gundagai to Maude)	Murrumbidgee River (Balranald to Murray River junction)	Yanco Creek System
Osprey	*Pandion haliaetus*						V		x			
Pacific golden plover	*Pluvialis fulva*	M							x			
Painted honeyeater	*Grantiella picta*					*	V	x	x	x		x
Pectoral sandpiper	*Calidris melanotos*	M							x			
Pied honeyeater	*Certhionyx variegatus*						V	x	x	x	x	x
Plains-wanderer	*Pedionomus torquatus*	V		*		*	E	x	x	x		x
Purple-crowned lorikeet	*Glossopsitta porphyearocephala*						V			x	x	
Purple-gaped honeyeater	*Lichenostomus cratitius*						V	x			x	
Rainbow bee-eater	*Merops ornatus*	M		*				x	x		x	x
Red knot	*Calidris canutus*	M							x			
Red-capped plover	*Charadruis ruficapillus*	M							x			
Red-lored whistler	*Pachycephala rufogularis*	V					E		x			
Red-necked avocet	*Recurvirostra novaehollandiae*	M							x			
Red-necked stint	*Calidris ruficollis*	E	*	*	*			x	x			
Redthroat	*Pyearrholaemus brunneus*						V	x		x	x	
Regent honeyeater	*Xanthomyza phrygia*	E		*		*	E	x	x	x		E1
Regent parrot (eastern subspecies)	*Polytelis anthopeplus monarchoides*	V					E	x		x	x	

Common name	Scientific name	EPBC Act	CAMBA	JAMBA	ROKAMBA	IUCN Red list	TSC Act	Lowbidgee	MIA	Murrumbidgee River (Gundagai to Maude)	Murrumbidgee River (Balranald to Murray River junction)	Yanco Creek System
Ruddy turnstone	*Arenaria interpres*	M							x			
Ruff	*Philomachus pugnax*	M							x			
Satin flycatcher	*Myiagra cyanoleuca*	M										x
Scarlet robin	*Petrioca boodang*						V		x	x		
Sharp-tailed sandpiper	*Calidris acuminata*	M	*	*	*			x	x			
Shy heathwren	*Hylacola cauta*						V		x	x	x	
Southern scrub-robin	*Drymodes brunneopygia*						V		x		x	
Speckled warbler	*Pyearrholaemus saggitatus*						V	x	x	x	x	
Spotted harrier	*Circus assimilis*						V	x	x	x	x	x
Square-tailed kite	*Lophoictinia isura*						V	x	x	x	x	
Superb parrot	*Polytelis swainsonii*	V				*	V	x	x	x	x	x
Swift parrot	*Lathamus discolor*	E				*	E	x	x	x	x	x
Thick-billed grasswren	*Amytornis textilis modestus*	V							x			
Turquoise parrot	*Neophema pulchella*						V		x	x		
Varied sitella	*Daphoenositta chrysoptera*						V		x		x	x
White fronted chat	*Epthianura albifrons*						V					x
White-bellied sea-eagle	*Haliaeetus leucogaster*	M	*					x	x		x	x
White-browed treecreeper population in Carrathool LGA	*Climacteris affinis*	End. Pop.					E		x			

Common name	Scientific name	EPBC Act	CAMBA	JAMBA	ROKAMBA	IUCN Red list	TSC Act	Lowbidgee	MIA	Murrumbidgee River (Gundagai to Maude)	Murrumbidgee River (Balranald to Murray River junction)	Yanco Creek System
White-fronted chat	*Epthianura albifrons*						V	x	x	x	x	
White-throated needletail	*Hirundapus caudacutus*	M	*	*	*			x	x		x	x
Wood sandpiper	*Tringa glareola*	M							x			
Fish												
Macquarie perch	*Macquaria australasica*	E					E (FM)	x	x	x	x	x
Murray cod, cod, goodoo	*Maccullochella peelii peelii*	V				*	V (FM)	x	x		x	x
Murray hardyhead	*Craterocephalus fluviatilis*	V					E (FM)	x		x	x	x
Freshwater catfish	*Tandanus tandanus*						End. Pop.	x		x		
Olive perchlet	*Ambassis agassizii*						End. Pop.	x				
Purple-spotted gudgeon	*Mogurnda adspersa*						E	x				
Silver perch	*Bidyanus bidyanus*						V	x		x		
Southern pygmy perch	*Nannoperca australis*						E	x		x		
Trout cod	*Maccullochella macquariensis*	E				*	E (FM)	x	x	x		x
Frogs												
Booroolong frog	*Litoria booroolongensis*	E								x		
Painted burrowing frog	*Neobatrachus pictus*						E	x				

Common name	Scientific name	EPBC Act	CAMBA	JAMBA	ROKAMBA	IUCN Red list	TSC Act	Lowbidgee	MIA	Murrumbidgee River (Gundagai to Maude)	Murrumbidgee River (Balranald to Murray River junction)	Yanco Creek System
Sloane's froglet	*Crinia sloanea*	V					V		x	x		x
Southern bell frog	*Litoria raniformis*	V				*	E	x	x	x	x	x
Mammals												
Bolam's mouse	*Pseudomys bolami*						E	x			x	
Brush-tailed phascogale	*Phascogale tapoatafa*						V		x	x		
Eastern bentwing-bat	*Miniopterus schreibersii oceanensis*						V			x		
Eastern long-eared bat	*Nyctophilus timoriensis*	V					V	x				
Eastern pygmy-possum	*Cercartetus nanus*						V			x		
Fishing bat	*Myotis macropus*						V	x				
Greater long-eared bat, South-eastern long-eared bat	*Nyctophilus timoriensis (South-eastern form)*	V					V		x	x	x	x
Inland forest bat	*Vespadeuls baverstocki*						V		x	x	x	
Koala	*Phascolarctos cinereus*						V		x	x		x
Little pied bat	*Chalinolobus picatus*						V		x	x	x	
Long-haired rat	*Rattus villosissimus*						V				x	
Mitchell's hopping-mouse	*Notomys mitchellii*						E				x	
Pig-footed bandicoot	*Chaeropus ecaudatus*						E				x	
Southern myotis	*Myotis macropus*						V		x	x		x
Southern ningaui	*Ningaui yvonneae*						V		x		x	

Common name	Scientific name	EPBC Act	CAMBA	JAMBA	ROKAMBA	IUCN Red list	TSC Act	Lowbidgee	MIA	Murrumbidgee River (Gundagai to Maude)	Murrumbidgee River (Balranald to Murray River junction)	Yanco Creek System
Spotted-tail quoll	*Dasyurus maculatus*	E					V	x	x	x	x	x
Squirrel glider	*Petaurus norfolcensis*						V			x		
Western pygmy possum	*Cercartetus concinnus*						E				x	
Yellow-bellied glider	*Petaurus australis*						V			x		
Yellow-bellied sheathtail-bat	*Saccolaimus flaviventris*						V			x		
Reptiles												
Bardick	*Echiopsis curta*						E				x	
Jewelled gecko	*Diplodactylus elderi*						V				x	
Mallee worm-lizard	*Aprasia inaurita*						E		x		x	
Pink-tailed legless lizard	*Aprasia parapulchella*	V					V			x		
Rosenberg's goanna	*Varanus rosenbergi*						V			x		
Striped legless lizard	*Delma impar*					*	V			x		x
Western blue-tongued lizard	*Tiliqua occipitalis*						V	x	x	x	x	
Plants												
A spear-grass	*Austrostipa metatoris*	V					V	x	x		x	
A burr-daisy	*Calotis moorei*						E			x		
A slender vine	*Tylophora linearis*	E							x			
A spear-grass	*Austrostipa wakoolica*	E							x	x		

Common name	Scientific name	EPBC Act	CAMBA	JAMBA	ROKAMBA	IUCN Red list	TSC Act	Lowbidgee	MIA	Murrumbidgee River (Gundagai to Maude)	Murrumbidgee River (Balranald to Murray River junction)	Yanco Creek System
Austral pillwort	*Pilularia novae-hollandiae*						E			x		
Austral pipewort	*Eriocaulon australasicum*	E					E	x				
Bindweed	*Convolvulus tedmoorei*						E			x		
Chariot wheels	*Maireana cheelii*	V						x		x		
Claypan daisy	*Brachyscome muelleroides*	V					V			x		
Cotoneaster pomaderris	*Pomaderris cotoneaster*						E			x		
Crimson spider orchid	*Caladenia concolor*	V					E			x		
Dwarf bush-pea	*Pultenaea humilis*						V			x		
Floating swamp wallaby-grass	*Amphibromus fluitans*	V					V			x		
Lanky buttons	*Leptorhynchos orientalis*						E		x	x		
Menindee nightshade	*Solanum karsense*	V						x		x	x	
Mossgiel daisy	*Brachyscome papillosa*	V					V	x	x	x		
Mueller's eyebright	*Euphrasia collina subsp. muelleri*						E			x		
Pine donkey orchid	*Diuris tricolor*						V		x	x		
River swamp wallaby-grass	*Amphibromus fluitans*	V						x	x			
Sand-hill spider orchid	*Caladenia arenaria*	E					E		x	x		
Silky swainson-pea	*Swainsona sericea*						V			x		
Slender darling-pea, Slender swainson, murray swainson-pea	*Swainsona murrayana*	V					V	x	x	x	x	

Common name	Scientific name	EPBC Act	CAMBA	JAMBA	ROKAMBA	IUCN Red list	TSC Act	Lowbidgee	MIA	Murrumbidgee River (Gundagai to Maude)	Murrumbidgee River (Balranald to Murray River junction)	Yanco Creek System
Small purple-pea	*Swainsona recta*						E			x		
Small scurf-pea	*Cullen parvum*						E			x		
Southern pipewort	*Eriocaulon australasicum*	E					E	x				
Spike-rush	*Eleocharis obicis*	V					V		x			
Spiny pepper-cress	*Lepidium aschersonii*	V							x	x		
Tarengo leek orchid	*Prasophyllum petilum*						E			x		
Tumut grevillea	*Grevillea wilkinsonii*						E			x		
Western water-starwort	*Callitriche cyclocarpa*	V							x			
Winged peppercress	*Lepidium monoplocoides*	E					E	x	x	x	x	
Woolly ragwort	*Senecio garlandii*	V					V			x		
Yass daisy	*Ammobium craspedioides*	V					V			x		
Yellow swainson-pea	*Swainsona pyearophila*	V									x	
Invertebrates												
River snail	*Notopala sublineata*						E	x		x		
Golden sun moth	*Synemon plana*									x		
Endangered Ecological Communities												
Buloke Woodlands of the Riverina and Murray-Darling Depression Bioregions		E						x	x		x	x
Weeping Myall Woodlands		E						x	x		x	x

Common name	Scientific name	EPBC Act	CAMBA	JAMBA	ROKAMBA	IUCN Red list	TSC Act	Lowbidgee	MIA	Murrumbidgee River (Gundagai to Maude)	Murrumbidgee River (Balranald to Murray River junction)	Yanco Creek System
White Box-Yellow Box-Blakely's Red Gum Grassy Woodland and Derived Native Grassland		E					E	x	x	x	x	x
Lowland Murray River Aquatic Ecological Community							E (FM)	x		x		x
Grey Box (*Eucalyptus microcarpus*) Grassy Woodlands and Derived Native Grasslands of South-eastern Australia		E									x	x
Acacia melvillei Shrubland in the Riverina and Murrya-Darling Depression Bioregions		E					E		x	x		
Inland Grey Box Woodland in the Riverina; NSW South Western Slopes; Cobar Peneplain; Nandewar and Brigalow Belt South Bioregions							E		x			
Myall Woodland in the Darling Riverine Plains; Brigalow Belt South; Cobar Peneplain; Murray-Darling Depression; Riverina and NSW South Western Slopes bioregions							E		x	x		
Sandhill Pine Woodland in the Riverina; Murray-Darling Depression and NSW South Western Slopes bioregions							E		x	x		
Inland Grey Box Woodland in the Riverina, NSW South Western Slopes, Cobar Peneplain, Nandewar and Brigalow Belt South Bioregions							E			x		

Appendix C
Environmental asset selection

Definition of water-dependent environmental assets

Environmental assets as defined by the *Water Act 2007* include water-dependent ecosystems and services, and sites of ecological significance. More specifically, these are defined as wetlands of high conservation value, river reaches, floodplains, groundwater-dependent ecosystems (GDEs), endangered ecological communities (EECs) and species reliant on freshwater systems, important drought refuge areas and ecosystem services.

Method for selection of environmental assets

The method for selection of environmental assets involved preliminary identification of potential assets, then a systematic analysis of each asset according to the following criteria:

1. Does the site hold significant ecological value?
2. Is water management the primary factor influencing condition of the asset? That is, will the application of environmental water maintain or improve condition of the site, or are there other prevailing (management) issues that mean altering the current watering regime would not contribute to maintaining or improving asset condition?
3. Are there logistic or other issues related to manipulating the current watering regime that preclude the asset from inclusion in an environmental watering program?

Creating a preliminary list of assets was achieved via a combined search of relevant databases (e.g. Ramsar Convention and Directory of Important Wetlands), and published and unpublished (grey) literature, and through consultation with relevant stakeholders in the catchment (e.g. agency and CMA staff, researchers). Any previous efforts to identify assets in the catchment in the literature were also consulted. The preliminary list included all biotic and abiotic assets according to the *Water Act 2007* definition, such as important wetlands, threatened species, and endangered ecological communities.

Appendix D
Asset condition and antecedent watering

Asset condition*

The environmental assets are a mix of wetlands and floodplains that are locally, regionally and/or nationally significant. Aquatic, riparian and floodplain habitats at the sites support various other biotic assets (including EECs and threatened species), and may be important as breeding, refuge and/or foraging habitat for freshwater dependent fauna. The location of each asset is depicted in Chapter 1. A description of the condition of assets in the water management areas is provided in Table A.

Antecedent watering catchment-wide synopsis

Drought conditions commenced in 2002–03 in southern NSW, with the first Exceptional Circumstances provisions for the Murrumbidgee River catchment declared in 2006. The drought continued until 2010, when median rainfall conditions were predicted. In December 2010 the Murrumbidgee River was in flood, with river heights rising from approximately 7 metres at Wagga Wagga on 3 December 2010 to peak between 9 and 10 metres on 7 December 2010. This created flood conditions throughout the Murrumbidgee River floodplain from Gundagai to Narrandera. (River heights of 8 to 10 metres at Wagga Wagga are correlated with minor to major flooding in the catchment, with the largest recent floods experienced in 1974 (10.74 metres) and 1991 (9.61 metres).) The flood peak inundated river-fed wetlands throughout the Murrumbidgee River catchment, culminating in high flow and flood conditions in floodplain wetlands downstream of Balranald through to the Murray River (in January 2011).

Environmental asset watering history*

Specific watering histories of the targeted environmental assets are presented in Table A. In general, managed flows were used to water assets throughout Yanga National Park in the 2009–10 watering year. Increasing rainfall in 2010 enabled the watering requirements of most assets in the park to be satisfied, with no likely requirement for further watering in the immediate future (except southern bell frogs and colonial breeding waterbirds which may require further water at selected sites to complete breeding events). Other sites in the catchment range in their time since last watering from the late 1980s and early 2000s, to last year (2010). The Yanco Creek system (including Billabong and Forest Creeks, and Wanganella Swamp) flooded in late 2010, such that Wanganella Swamp supported a colonial bird breeding event. Alternatively, much of the Mirrool Creek system has experienced only minor flows since the last end of system flow in 1989.

The watering history of core southern bell frog and colonial breeding waterbirds is presented in Table B. The species has also been recorded recently (December 2010) at two Mid-Murrumbidgee wetlands (Gooragool Lagoon in Cuba National Park, and Sunshower Lagoon).

** Please note that information on the 2010 condition and antecedent watering regime of assets is patchy. For example, the condition and watering history of some sites in the Lowbidgee is well known because these have been targeted for active management to maintain their habitat value through the recent drought; however less information is available for other sites, such as the Lower Mirrool Creek Floodplain, and many of the Mid-Murrumbidgee wetlands.*

Table A: Environmental assets in the Murrumbidgee, and their watering history and current condition (as of October 2011).

Environmental asset	Watering history	Current condition
1. Murrumbidgee River (Gundagai to Maude)	Information on the watering history of Mid-Murrumbidgee wetlands is piecemeal because there is so many of them they are managed by different agencies, natural resource management organisations and private landholders, each with their own management focus and priorities. The following dot points provide more specific information for some Mid-Murrumbidgee wetlands.	• The condition of Mid-Murrumbidgee wetlands was considered critical and declining in 2009, with condition worsening from the uplands in the east to the lowlands in the west of the catchment. • In general, recent natural flooding (spring and summer 2010–11) will have alleviated stress on some wetlands, and provided flushing flows for others, and their condition can be expected to improve in the short-term.
	• Selected IMEF sites were watered in 2000, 2001 and 2005. Then all sites were watered in 2009, and again in late 2010 when the Murrumbidgee River naturally inundated. (IMEF sites include Sunshower Lagoon, Berryjerry Lagoon, Iris Swamp Lagoon, Molly's Lagoon—Dry Lake, and Gooragool Lagoon.)	• IMEF sites were considered in critical-to-poor condition in August 2009. • The IMEF sites would have been naturally inundated in late 2010, and are currently wet or drying.
	• Most river-fed wetlands in the Murrumbidgee River floodplain from Burrinjuck/Blowering Dams to Narrandera were watered in spring 2000 or spring 2005.	• Sites were considered in poor-to-good condition in August 2009. • These sites would have been naturally inundated in late 2010, and are currently wet or drying.
	• Some Carrathool to Maude Weir floodplain wetlands were watered 1996, and others in 2000.	• These wetlands were considered in critical to poor condition in August 2009. • Some of these sites would have been naturally inundated in late 2010, and are currently wet or drying.
	• Maude Weir Lagoon was filled in December 2009 with approximately 30 ML of EWA, then topped up with approximately 3 ML of EWA in December 2009 and again in May 2010.	• No information relating to the specific condition of Maude Weir Lagoon was available. Given its location in the lowlands of the floodplain it is assumed the lagoon was in poor condition prior to watering in 2009. If the lagoon was inundated during the recent natural flood, its condition may have improved, at least for the short-term.
2. Fivebough Swamp	• Fivebough Swamp received EWA water in 2005. Then in May 2010 it was inundated with 1,019 ML of EWA. On this occasion the site was filled to its highest level in more than 10 years.	• Although altered from its natural condition, Fivebough Swamp is considered in good condition (M Schultz (Fivebough & Tuckerbil Wetlands Trust) 2011, pers. comm., 8 November).
3. Tuckerbil Swamp	• Tuckerbil Swamp was watered using 500 ML of EWA in 2005. Since 2005 it would have received intermittent inflows from local rainfall events.	• Although altered from its natural condition, Tuckerbil Swamp is considered in reasonable condition (M Schultz (Fivebough & Tuckerbil Wetlands Trust) 2011, pers. comm., 8 November).

Environmental asset	Watering history	Current condition
4. Barren Box Swamp	• Barren Box Swamp was used as a drainage basin for Murrumbidgee Irrigation Limited water, so it was permanently wet from the 1970's to 2003. Works commenced in 2005 divided the wetland into three management 'cells', with one designated as a rehabilitation area for wetland habitat. This 'wetland cell' dried in 2003, until it was watered in October/November 2010.	• Barren Box Swamp was previously in poor condition, with the wetland cell supporting numerous weeds, and dry since 2003. The wetland cell is currently managed as per the Barren Box Wetland Rehabilitation Plan (MI 2008), which aims to protect and enhance the environmental values of the wetland. • Aerial seeding of black box was planned for late November 2010. • Control of alligator weed is ongoing in the Swamp system.
5. Lower Mirrool Creek Floodplain	The last end-of-system flow in the Lower Mirrool Creek (to the Lachlan River) was in 1989. Prior to 2003 small 'forced releases' routinely inundated the floodplain immediately west of Barren Box Swamp. This ceased by chance in 2003, when the drought dried Barren Box Swamp, and then by design in 2005 when works at Barren Box Swamp were commenced to improve its efficiency. High summer rainfall in summer 2010 filled wetlands throughout the system, with some flows reported in the lower reaches of Mirrool Creek (J Maguire (OEH) 2011, pers. comm., 9 August).	The floodplain is currently considered in poor-to-critical condition. Areas downstream of Barren Box Swamp were overwatered for decades, leading to a decline in their condition. Black box woodland and associated wetlands further west in the floodplain are also considered in poor to critical condition, but from a lack of water.
6. Lowland river-fed wetlands (Balranald to Murray River junction, including 'the Junction' wetlands)	Targeted billabongs were watered by OEH.	Condition is considered poor. Some wetlands have not been watered since 2000.

Environmental asset	Watering history	Current condition
7. Lowbidgee Wetlands (*also see Table below*)	The North Redbank system experienced good flooding as far south as Glen Avon in 2010. As the lower end of the North Redbank wetland (off North Redbank Channel on the Lowbidgee floodplain) 3000 ha of river red gum wetlands were inundated in autumn 2010 using 1,600 ML of CEW supplementary water, 400 ML of NSW supplementary water, 1,000 ML of Lowbidgee share, and 5,000 ML of NSW environmental water allowance water. This was the first watering for five years. 1,800 ha of Paika-Narwhie was flooded with NSW environmental water allowance in winter 2009 and dried out by the summer of the same year. This was the first watering for four years in that system. The upper end of Redbank Channel (i.e. Paul Coates Swamp) was flooded in 2007–08 and 2008–09. The mid-upper sections of North Redbank wetlands are currently experiencing good flooding as a result of tributary flows. 15,000 ML released in October 2010 completed watering of the Redbank system by finishing watering of the section from Glen Avon through Auley, Moola, Riverleigh, Baupie and Balranald Common, and prolong the flooding to this area and the remainder of the North Redbank system (which was already flooded—estimate to require approximately 50 ML/d for 100 days).	Current condition is considered good.
	Core Southern Bell Frog wetlands in Yanga (Twin Bridges-Piggery Lake complex) were watered in summer 2008, and again in summer 2009. (Required 1,700 ML of EWA and 1,661 OEH licence water and 7,096 CEW (total 10,457 ML)).	Current condition is considered good.
	River red gum forest in North Yanga was watered summer 2005, then again in 2009 and 2010.	Current condition is considered good.
	Core southern bell frog wetlands in Nimmie-Caira were watered in summer 2008 and 2009.	Current condition is considered good.
	River Red Gum Forest in the southern portions of South Yanga were watered in 2000 and then again in 2009 and 2010.	Its condition in 2000 was considered critical, however recent watering may have improved this.
	Tala Lake filled and was overflowing down Tala and Woolshed Creek into the southern section of Yanga National Park in July 2010. By August, water had spread through southern sections of Yanga National Park down to the Devil's Creek regulator just north of Yanga Lake. This is the largest high flow event in Yanga National Park for at least 10 years, with 16,000 ha inundated.	

Environmental asset	Watering history	Current condition
8. Yanco Creek System	Forest Creek and Wanganella Swamp were isolated from the Yanco Creek system in 2007, as part of water savings measures for the Snowy River system. Forest Creek is currently flowing, and Wanganella Swamp is full.	The Yanco Creek system is considered in good condition.

Table B: Recent watering history of core southern bell frog and colonial waterbird habitat in the Lowbidgee.

Locality	Site	2008–09	2009–10
Nimmie-Caira	Eulimbah Swamp Rookery		
Nimmie-Caira	Suicide Bank Rookery/Torry Plains Stock Dam		
Nimmie-Caira	North and South Lees Bank Rookery		
Nimmie-Caira	Pollen Dam		
Nimmie-Caira	Nap Nap Swamp Rookery		X
Nimmie-Caira	Nap Nap Creek Paddock Woodland		
Nimmie-Caira	Monkem Creek	X	X
Nimmie-Caira	Wagourah Lagoon	X	X
Nimmie-Caira	Warwaegae Swamp	X	X
Nimmie-Caira	Telephone Creek	X	X
Nimmie-Caira	Telephone Bank Rookery		
Nimmie-Caira	Littlewood Swamp Rookery		
Nimmie-Caira	Talpee/Pee Vee Creek Rookery		
Nimmie-Caira	Avalon North Rookery	X	X
Fiddlers-Uara	Loorica Lake/Nolan's Chance Lake		
Fiddlers-Uara	Warwaegae Swamp		
Fiddlers-Uara	Loorica Road Borrow Pit		
Fiddlers-Uara	South Eulimbah Swamp/South Eulimbah Stock Dam	X	X
Yanga	Mercedes/Redbank Swamp	X	X
Yanga	Pococks/Freddys Swamp		
Yanga	Piggery Lake Complex		X
Yanga	Two Bridges/Twin Bridges/Avenue Swamp	X	X
Yanga	Top Narockwell System		X
Yanga	Lake Tala		X
Redbank North	Narwhie-Paika/Steam Engine Narwie Complex		X
Redbank North	Paul Coates Swamp	X	
Redbank North	1AS Regulator Channel	X	X
Redbank North	North Redbank Channel	X	
Yanga	North Stallion Swamp		X

Appendix E
Watering requirements of environmental assets

Asset	Avoid fatality maintain	Maintain	Recruit
River red gum (*Eucalyptus camaldulensis*)	Average inundation duration 4–7 months, occurring in winter-spring and not lasting more than 24 months continuous inundation or 24 months without inundation. Complete drying in-between inundation.	• Average inundation frequency of 1–3 years • Average duration 4–7 months, occurring in winter-spring and not lasting more than 24-months continuous flooding or 24 months without inundation. • Duration can be supplemented by summer floods, although repeated summer high flows will alter the understorey. • Inundation frequency and duration may need to be reduced if the water table is shallow or trees have access to permanent water. • Complete drying in-between cycles is needed as much as possible, to ensure soil cracking for aeration and deep re-charge.	• A high flow event extending well into late spring or early summer, followed by wet winter-spring or shallow and brief/pulsed winter-spring floods, and even brief or shallow summer inundation.
Black box (*Eucalyptus largiflorens*)	May tolerate an inundation frequency of 1 in 7–10 years. Do not inundate for longer than 1 year.	• Inundation for 2–4 months optimum. • May survive up to 1 year of inundation (but not every year). • Will survive even longer periods of inundation but is likely to lose vigour. • Inundation frequency of 1 in 3–5 years, but may tolerate 7–10 years.	• Depth: 1–30 cm • Duration: 1–50 days • Timing: winter-spring • Extensive high flows long enough to saturate surface soil, with slow recession.
Lignum (*Muehlenbeckia florulenta*)	Do not inundate for longer than 12 months. Requires complete drying between periods of inundation. Must water every 8 years.	• Inundation for 3–12 months. • Tolerance of up to 1 year (but not every year). Continuously wet should be avoided. • Inundation frequency of an average 2–8 years • Although it can tolerate up to 10 years dry this will cause stress and loss of vigour and loss of above-ground material. • Complete drying between periods of inundation is essential to ensure soil aeration, soil water recharge and to preserve crack habitat for small native animals. • Optimum timing is unknown, but thought to be spring-summer.	• Depth: 10–30 cm. • Duration: 10–40 days. • Dry period required, ideally within 30 days of the wet period. Germination is temperature controlled, not favourable in the winter months. • Timing of high flows may be critical with summer floods lasting long enough to wet the soil profile thought to be critical.
Southern bell frog (*Litoria raniformis*)	Must be watered every year.	• Annual watering at key source habitats in spring and summer. • Can use permanent water habitats, so would tolerate year-round watering.	• Annual watering at key source habitats, plus adjacent suitable habitats. • Ensure follow-up watering. • Spring and summer minimum 10 months duration.

Asset	Avoid fatality maintain	Maintain	Recruit
Colonial nesting waterbirds	Selected key rookeries should be watered annually, in conjunction with objectives for key vegetation communities at the various sites.	• Waterbirds require a range of open water and muddy shore habitats to forage in, and for refuge. Many will travel between wetlands in various stages of wetting and drying to forage, so a mosaic of suitable habitats throughout the landscape will support the most diverse waterbird community. • In terms of refuge, most waterbirds require slow-to-still waters, with varying needs for water depth, exposure and gradient of banks, macrophyte growth and riparian habitats. Some species will also use slowly filling and receding habitats.	• Minimum required duration of inundation to support successful breeding for most waterbirds is approximately 5–8 months when inundation occurs in winter/spring (Scott 1997, Briggs & Thornton 1999). • For autumn floods 7–10 months inundation under nest trees is required. Ducks are an exception because they can breed successfully on shorter periods of inundation than darters, cormorants, herons, egrets ibis and spoonbills. They require 5–6 months of inundation in any season to complete their breeding (Briggs & Thornton 1999). • Therefore most species require inundation of their wetland and lake habitats a minimum duration of 5–10 months (Scott 1997). • Most species require their still or slow-flowing habitats to be inundated during the period September to December. • The timing of high flow events should be June-August • Stable water levels should be maintained during waterbird breeding seasons (September-March) • Water recession rates should at all times be slow (i.e. take three months) • All rookery areas should be dried out for a minimum period of one month and preferably 3–4 months every year.
Migratory waterbirds	Selected key areas should be watered annually, in conjunction with objectives for key vegetation communities at the various sites.	• In watering terms, provision of a mosaic of wetlands in the landscape at different stages of drying and filling is ideal. • In terms of refuge, most waterbirds require slow-to-still waters, with varying needs for water depth, exposure and gradient of banks, macrophyte growth and riparian habitats. Some species will also use slowly filling and receding habitats.	• Migratory waterbirds breed in the northern hemisphere, and then migrate to Australian habitats to forage. Therefore they don't 'recruit' in the Murrumbidgee.

Asset	Avoid fatality maintain	Maintain	Recruit
Murray cod (*Macchullochella peelii peelii*) (i.e. representative large-bodied fish)	Habitats cannot be allowed to completely dry.	• Requires seasonally appropriate within-channel variability, creating a range of foraging habitats. That is, higher water levels in late winter and spring, tapering into summer and autumn. • Maintenance of pool habitats with large woody debris. • Requires permanent water. • Responds to temperature changes in spring and summer by migrating upstream, so in-stream barriers are a significant constraint.	• High flow or natural flood events in spring may contribute to creating suitable conditions for Murray cod larvae. • Murray cod migrate upstream prior to spawning in late spring or early summer when day length increases and the water attains a temperature of 15–21°C (Gooley et al. 1995, Koehn & Harrington 2006). Females can lay up to 40,000 adhesive eggs which are deposited in hollow logs or shallow water (NRE 1998). Once hatched, the larvae drift downstream for 5–7 days, particularly by night in spring and summer, prior to settling out in suitable protected habitat (Lintermans 2007). • Although high flow events do not appear to trigger the spawning of Murray cod, strong year classes have been reported following breeding years that experience high flow or natural flood events. Periods of inundation during spring may be of particular importance for the survival of larvae (6–9 mm at hatching). Successful recruitment is also reliant on high flows which contribute to development of additional food sources that are essential to the survival of large numbers of Murray cod larvae and fry.
Un-specked hardyhead (*Craterocephalus stercusmuscarum fulvus*) (i.e. representative small-bodied fish)	Habitats cannot be allowed to completely dry. Floodplain wetland habitats cannot be allowed to drain too quickly so they cannot return to the main channel.	• Manage to maintain aquatic habitats in accordance with river red gum and southern bell frog 'maintenance' water requirements. • Un-specked Hardyhead prefer slow-flowing or still habitats with aquatic vegetation and sand, gravel or mud substrates (Lintermans 2007). In off-channel areas of the lower River Murray, the habitats of Un-specked Hardyhead are typically partially or fully connected to the channel, with a minimum depth of 0.5 m, with diverse macrophytes and abundant woody debris (Wedderburn et al. 2007).	• Provide flows to wetland habitats in spring and summer, to greater than 0.5 m depth. • The species spawns from October to February, with a peak in spring when water temperatures are above 24°C. Fecundity is usually low, but it is capable of multiple spawning during the breeding season. Little is known of its movements, but it has been recorded attempting to move upstream through fishways in the Murray and Murrumbidgee rivers (Lintermans 2007).
Freshwater catfish (*Tandanus tandanus*)	Habitats cannot be allowed to completely dry	• Maintain at minimum within-channel low-flow conditions. • Freshwater catfish is a relatively sedentary species, and shows limited movement compared to other similar-sized species in the same habitats; most individuals move less than 5 km. Hence the species is susceptible to changed flow regimes which decrease the area of aquatic habitat.	• Requires slow-flowing warm waters in spring and summer to encourage spawning. • Freshwater catfish is a benthic species that prefer slow-flowing streams and lake habitats. Individuals are sexually mature at 3–5 years of age and spawn in spring and summer when water temperatures are 20–24°C.
Common carp (*Cyprinus carpio*)	Controlling carp is best achieved by complete drying of habitats, and screening to exclude them.	• There isn't an achievable flow regime that could be used to select against maintenance of common carp in the Murrumbidgee. • Common carp are tolerant of a wide range of environmental conditions, and may be the most dominant fish species in off-river storages, dam reservoirs, weir pools and irrigation channels. In the Lowbidgee common carp are known to occupy irrigation channels, natural waterways and wetland habitats. Surveys conducted in 2009 (in the Lowbidgee) revealed the highest numbers of common carp were recorded in Mercedes Swamp in Yanga National Park.	• The species prefers warmer water temperatures in spring and summer for spawning. • Connectivity with floodplain wetlands is thought to provide young of the year with suitable habitat. However they can become stranded when the floodwaters recede and as billabongs dry up (Driver et al. 2005).

The following table cross-references the presence of biotic assets against the water management areas. This provides a link between determining the appropriate watering regime for a site based purely on its dominant vegetation community, and value for threatened or otherwise important fauna and flora. For the most part the watering requirements of flora and fauna at a site will generally coincide, allowing an overall watering regime for a site to be created. However, some inconsistencies may occur. For example, the recommended regime for watering southern bell frogs is annual inundation of their core habitats to support breeding and recruitment. For this species successful recruitment every year is critical to survival of their population in the district, but their river red gum wetland habitats may not benefit from repeated annual inundation. Hence, watering to maintain habitat for the species, and support annual breeding events and recruitment will need to be carefully managed to ensure core habitats are not over-watered in the short-term such that their usefulness to the Southern Bell Frog is compromised in the long-term. This will require adoption of a coordinated and strategic approach whereby suitable wetlands are watered in a sequence that allows the frog to move between them and recruit successfully.

	River red gum forest	River red gum woodland	Black box	Lignum	Southern bell frog	Colonial breeding waterbirds	Migratory waterbirds	Other
1. River-fed wetlands (Gundagai to Maude—includes the Mid-Murrumbidgee wetlands).	✓		✓	✓	✓	✓	✓	Small and large-bodied fish
2. Fivebough Swamp							✓	Reed wetlands
3. Tuckerbil Swamp						✓	✓	Brackish (samphire/seablite) wetland
4. Barren Box Swamp			✓			✓	✓	
5. Lower Mirrool Creek Floodplain			✓	✓				
6. Lowland river-fed wetlands (Balranald to Murray River junction, including 'the Junction' wetlands)	✓			✓		✓	✓	Small and large-bodied fish
7. Lowbidgee Wetlands	✓	✓		✓	✓	✓	✓	
8. Yanco Creek System	✓		✓			✓	✓	Reed wetlands Freshwater catfish

Appendix F
Commonwealth environmental watering objectives

	Ecological Watering Objectives	Management Objectives	Management Actions
Extreme Dry	• Avoid damage to key environmental assets	• Avoid critical loss of threatened species and communities • Maintain key refuges • Avoid irretrievable damage or catastrophic events	• Water refugia and sites supporting threatened species and communities • Undertake emergency watering at specific sites of priority assets • Use carryover volumes to maintain critical needs
Dry	• Ensure ecological capacity for recovery	• Support the survival and growth of threatened species and communities, including limited small-scale recruitment • Maintain diverse habitats • Maintain low-flow river and floodplain functional processes in sites and reaches of priority assets	• Water refugia and sites supporting threatened species and communities • Provide low flow and freshes in sites and reaches of priority assets • Use carryover volumes to maintain follow-up watering
Median	• Maintain ecological health and resilience	• Enable growth and reproduction and large-scale recruitment for a diverse range of flora and fauna • Promote higher floodplain-river connectivity • Support high-flow river and floodplain functional processes	• Prolong flood/high-flow duration at key sites and reaches of priority assets • Contribute to the full range of in-channel flows • Use carryover to provide optimal seasonal flow patterns in subsequent years
Wet	• Improve and extend healthy and resilient aquatic ecosystems	• Enable growth, reproduction and large-scale recruitment for diverse flora and fauna • Promote higher floodplain-river connectivity • Support high-flow river and floodplain functional processes	• Increase inundation duration and extent across priority assets • Contribute to the full range of flows, including overbank • Provide Use carryover water to optimal seasonal flow patterns in subsequent years

Appendix G
Commonwealth environmental watering program operational monitoring report proforma

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	**<EWDS to prefill>**	**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) <EWDS to prefill>*	
	Total volume of water allocated for the watering event *CEW:* *Other(please specify) :*	
	Total volume of water delivered in watering event *CEW:* *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]	

Appendix H
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

WAT086.0211

Australian Government

Commonwealth Environmental Water

ENVIRONMENTAL WATER DELIVERY

Namoi River

MARCH 2012 V1.0

Image Credits

The Namoi River near Walgett
© MDBA; Photographer Arthur Mostead

River red gum
© MDBA; Photographer John Baker

Barma Water Resources, Thurtell, L and Wettin, P (2012). *Environmental Water Delivery: Namoi River.* Prepared for Commonwealth Environmental Water, Department of Sustainability, Environment, Water, Population and Communities, Canberra.

ISBN: 978-1-921733-50-5

Commonwealth Environmental Water acknowledges the following individuals and organisations that have been consulted in the preparation of this document:

F. Andreoni (Namoi CMA)
C. Cahill (State Water)
K. Gee (State Water)
S. Samarawickrama (State Water)
W. Mahwinney (NSW Office of Water)
N. Foster (NSW Office of Water)
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Published by the Commonwealth Environmental Water Office for the Australian Government.

ENVIRONMENTAL WATER DELIVERY

Namoi River

MARCH 2012 V1.0

Environmental Water Delivery: Namoi River

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

- 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 options for environmental water use in the Namoi catchment. As the first version of the document, it is intended to provide a starting point for discussions on environmental water use. As such, suggestions and feedback on the document are encouraged and will be used to inform planning for environmental water use and future iterations of the document.

The Namoi catchment supports significant conservation values including numerous threatened native flora and fauna, as well as bird species protected under international migratory bird agreements. Potential water use options for the Namoi River include contributing to baseflows along the river channel to maintain in-stream refuges and aquatic habitat for native fish; provisions of inflows to support water plants for wetland habitat condition in anabranches between Mollee and Gunidgera Weirs and in Duncans Warrambool; and provision of freshes to trigger native-fish spawning and recruitment in river channel and creeks.

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 NSW Office of Water, Namoi CMA and State Water.

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

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Abbreviations

Acronym	Meaning
AEW	Adaptive Environmental Water
AEMP	Adaptive Environmental Management Plan
CAMBA	China-Australia Migratory Bird Agreement
CEWH	Commonwealth Environmental Water Holder
CMA	Catchment Management Authority
CSIRO	Commonwealth Scientific and Industrial Research Organisation
DECCW	Department of Climate Change and Water (NSW)
DEWHA	Department of Environment, Water, Heritage and the Arts (Cwth)
DIPNR	Department of Planning Infrastructure and Natural Resources (NSW)
DLWC	Department of Land and Water Conservation (NSW)
DOC	Dissolved organic carbon
DPI	Department of Primary Industries (NSW)
d/s	Downstream
ECA	Environmental Contingency Allowance
EEC	Endangered Ecological Communities
EPBC	*Environmental Protection and Biodiversity Conservation Act 1999* (Cwlth)
EW	Environmental water
GAB	Great Artesian Basin
GIS	Geographic Information System
GL/d	Gigalitres per day
IMEF	Integrated Monitoring of Environmental Flows
IQQM	Integrated Quantity and Quality Model
ISRAG	Independent Sustainable Rivers Audit Group
IUCN	International Union for Conservation of Nature
JAMBA	Japan-Australia Migratory Bird Agreement
LTAAEL	Long-term average annual extraction limit
LTEL	Long-term extraction limit
MDBA	Murray-Darling Basin Authority

Acronym	Meaning
ML/d	Megalitres per day
NCMA	Namoi Catchment Management Authority
NOW	NSW Office of Water
NSW	New South Wales
OEH	Office of Environment and Heritage (NSW)
RCA	Riverine Condition Assessment
RERP	Rivers and Environment Restoration Program
ROKAMBA	Republic of Korea-Australia Migratory Bird Agreement
SEWPAC	Department of Sustainability, Environment, Water, Population and Communities (Cwth)
SRA	Sustainable Rivers Audit
u/s	Upstream
WMA	Water Management Area
WSP	Water Sharing Plan (for the Upper Namoi and Lower Namoi Regulated River Water Sources 2003 (New South Wales))
WUP	Water Use Plan

PART 1:
Management aims

1. Overview

1.1 Scope and purpose

Information provided in this document is intended to help establish an operational framework that provides scalable strategies for environmental water use based on the watering needs of selected assets.

This document outlines the processes and mechanisms that will enable water-use strategies to be implemented in the context of river operations and delivery arrangements, water trading and governance, constraints and opportunities. It specifically targets large-scale water-use options for the application of 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.

Information provided focuses on the environmental watering objectives and water use options for the Namoi River in New South Wales.

As part of this project, assets and potential watering options have been identified for regions across the Murray-Darling 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 options have been developed for each asset to meet watering objectives under a range of volume scenarios. Use of environmental water will aim to maximise environmental outcomes at multiple assets, where possible.
3. Processes and mechanisms required to operationalise environmental water delivery have been documented and include:
   - delivery arrangements and operating procedures
   - water-delivery accounting methods (in consultation with operating authorities) 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.

1.2 Catchment and river system overview

The Namoi River is one of the Murray-Darling Basin's major NSW sub-catchments. It covers a total area of about 42,000 square kilometres from the Great Dividing Range near Tamworth to the Barwon River near Walgett (Figure 1). The Peel River is a major regulated tributary to the Namoi with a catchment area of around 4,700 square kilometres (Figure 1). It contributes an average annual volume of approximately 280,000 megalitres to the Namoi River (Green et al. 2011).

The Namoi catchment borders the Gwydir and Castlereagh catchments and is bounded by the Great Dividing Range in the east, the Liverpool Ranges and Warrumbungle Ranges in the south, and the Nandewar Ranges and Mount Kaputar to the north. Elevations range from over 1,500 metres to the south and east to just 100 metres on the alluvial floodplain of the lower catchment west of Narrabri. Stretching from Bendemeer in the east to Walgett on the western boundary, the Namoi catchment is over 350 kilometres long (Green et al. 2011).

Major tributaries of the Namoi River include Cox's Creek and the Mooki, Peel, Manilla and McDonald Rivers joining the Namoi River upstream of Boggabri with Pian, Narrabri, Baradine and Bohena Creeks joining below Boggabri. Major tributaries of the Peel River are Goonoo Goonoo Creek, Cockburn River, and Dungowan Creek (Green et al. 2011).

A number of minor unregulated tributaries, originating from the Kaputar area, also provide high-volume storm flows which can contribute significantly to the Namoi River. The most significant of those is Maules Creek.

Streamflows in the Namoi catchment are regulated by Keepit Dam on the Namoi River, Split Rock Dam on the Manilla River and Chaffey Dam on the Peel River. The regulated section of the Peel River and the regulated section of the Namoi River between Split Rock and Keepit Dams have historically been managed as separate allocation schemes to the Namoi regulated river below Keepit Dam and operationally the management of Chaffey Dam is independent of the other storages on the Namoi (Green et al. 2011).

The annual regional output for the region is valued at over $1 billion, with dryland and irrigated agricultural production representing approximately half this amount. Major industries include cotton, livestock production, grain and hay, poultry, horticulture and forestry. The region's local councils also depend on the Namoi and Peel Rivers to meet the urban water requirements of the many urban centres with the most notable being the major centre of Tamworth whose water supply is provided from the Peel River (Green et al. 2011).

Approximately 100,000 people currently live within the Namoi catchment, mostly along the Namoi River and its tributaries between Tamworth and Narrabri. Tamworth, located on the Peel River, is the largest urban centre in the catchment with a population of nearly 33,500 people living in town. Gunnedah, on the Namoi River, has a population of 7,500 people, and Narrabri, also on the Namoi, has a population of 6,100 people. A number of smaller towns throughout the catchment, such as Barraba, Manilla, Quirindi, Walgett, Wee Waa and Werris Creek, support between 1,000 and 3,000 people (Green et al. 2011).

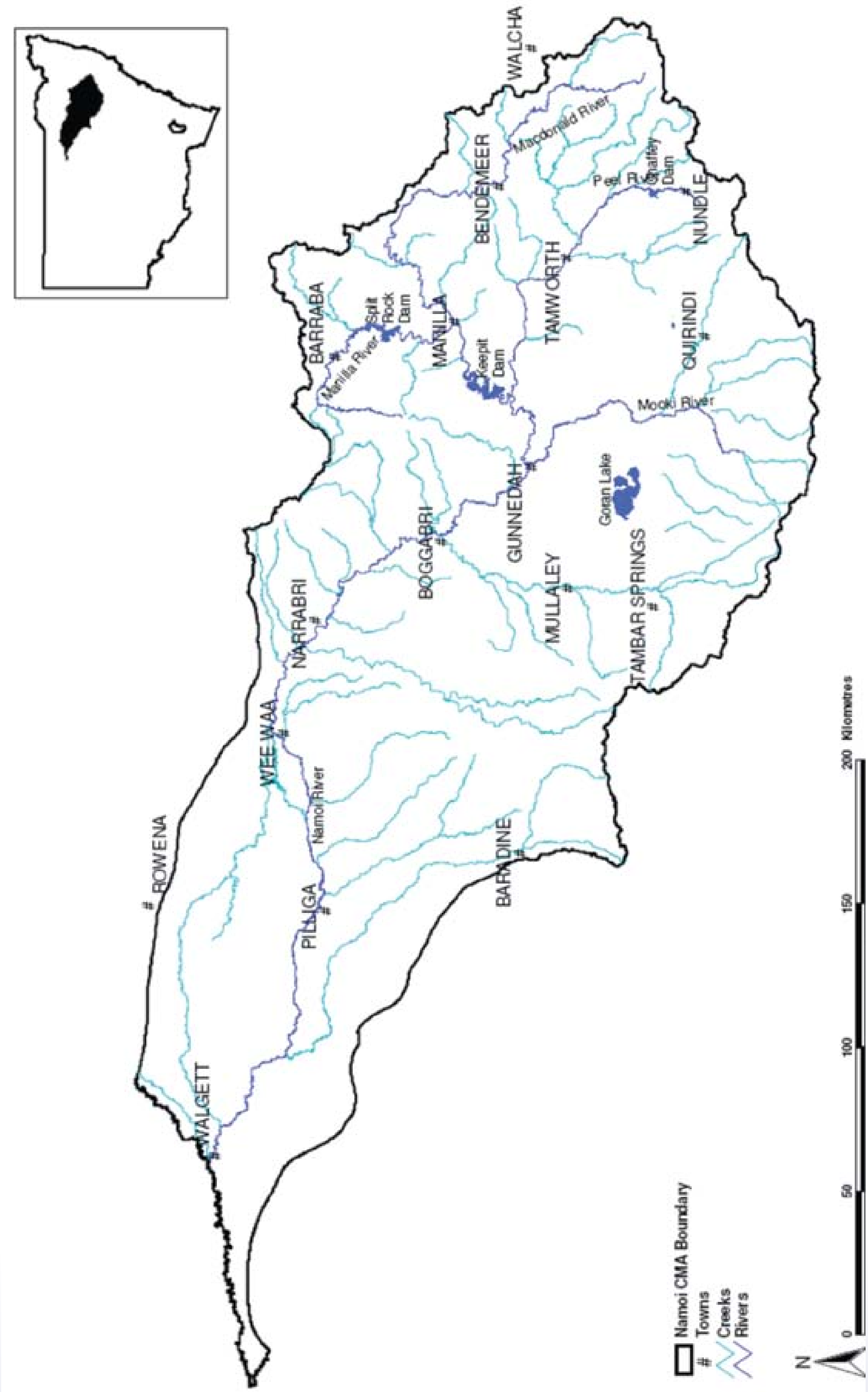

Figure 1: Namoi catchment (SEWPaC 2011)

The lower Namoi riverine plains have an elevation of approximately 150 metres above sea level and consist almost entirely of recent alluvium on flat topography. This flat topography facilitates the development of floodrunners, anabranches and warrambools (overflow channels which contain water only during flood times), throughout the lower Namoi (Foster 1999).

Narrabri Creek, originally a natural anabranch of the Namoi River, begins just upstream of Narrabri and rejoins the Namoi River just below the town. It is a significant feature of the lower catchment which has been significantly modified and now takes a majority of the flow, with the Namoi River only flowing when flow rates of 25,000 to 30,000 ML/d are reached on the Narrabri. Narrabri Creek is highly degraded and is actively widening through bank erosion and river bed aggradation. It has limited aquatic environmental value.

Downstream of Wee Waa, the Namoi River progresses into a distributary zone (Thoms et al. 1999). Small tributary creeks draining the Pilliga scrub to the south often contribute large volumes of water to the Namoi River and its adjacent floodplain wetlands. Near the town of Pilliga, the Namoi River splits into two channels for a distance of six kilometres. At this point in the catchment, Duncan's Warrambool, the northern channel, carries two-thirds of the river flow. This section of the Namoi River contains small areas of intact remnant riverine and wetland ecosystems. Between the Namoi River to the south and Pian Creek to the north are a number of ephemeral watercourses that flow westward across the floodplain.

From where Pian Creek leaves the Namoi River to the junction of the Namoi River with the Barwon River, the riverine and wetland environments are characterised by a complex pattern of anabranches, effluent channels, in-stream benches and small floodplain wetlands which are subject to extensive flooding, often inundated for many weeks. The riverine plain of this part of the Namoi merges with the floodplains of the neighbouring Gwydir and Castlereagh Rivers, and with the Barwon floodplain near Walgett.

The lower reaches of the Namoi River are dominated by coolibah (*Eucalyptus coolabah)*, river red gum (*Eucalyptus camaldulensis*) and river cooba (*Acacia stenophylla)* vegetation communities.

1.3 Overview of river operating environment

The following section identifies the main river-regulating structures and their purpose on the Namoi River.

Keepit Dam was completed in 1960 as the major irrigation storage for the Namoi catchment and has a storage capacity of 426,000 megalitres. It also supplies town water, provides for flood mitigation, and generates hydropower.

Split Rock Dam, on the Manilla River, has a capacity of 397,000 megalitres and was completed in 1987 to augment the supply from Keepit Dam as well as supplying users along the Manilla River. The two dams are operated as a joint water-supply system for the Namoi catchment (section 6 provides more details on how the stored water is jointly operated).

Chaffey Dam has a capacity of 62,000 megalitres and is approximately 45 kilometres south-east of Tamworth. Its prime purpose is to regulate the flow of the Peel River and for water supply for Tamworth. Tamworth City Council also owns and operates Dungowan storage for its water supply. An enlargement of Chaffey Dam has recently been approved to provide additional town water supply security for Tamworth and to improve the dam's flood safety. This enlargement will increase the current maximum storage to 100,000 megalitres.

Flows in the Namoi River are highly regulated: Split Rock Dam regulates 93 per cent of all inflows and Keepit Dam regulates 77 per cent of all inflows. Flows in the Peel River are less regulated with Chaffey Dam currently regulating 41 per cent of all inflows (CSIRO 2007).

There are three weirs situated on the Namoi River downstream of Narrabri. Mollee Weir has a storage capacity of 3,300 megalitres and is designed to hold and re-regulate flows to improve the delivery of water to the lower valley.

Gunidgera Weir is located just downstream of Wee Waa and has a storage capacity of 1,900 megalitres. The main function of the weir is for the control of regulated flows into Gunidgera and Pian Creeks.

Weeta Weir has a capacity of 280 megalitres to provide storage for downstream irrigators. However, a number of ongoing problems with the weir have prevented it being used for storage and it is currently being decommissioned.

There are also a number of small weirs on Pian Creek (Hazeldean, Greylands and Dundee Weirs) and Gunidgera Creek (Knights Weir) which assist in the provision of water for local water users.

1.4 Environmental water policy on the Namoi River

The key water legislation in NSW—the *Water Management Act 2000*—provides water for the environment in two ways: planned environmental water and adaptive environmental water. Planned environmental water is water prescribed for use under the rules of a Water Sharing Plan. Adaptive environmental water is water allowed to be taken and used for the environment under water access licences, where these licences have a condition specifying they are to be used for environmental purposes. The condition may be amended or revoked by the minister at the request in writing of the holder of the access licence, except as provided by the regulation.

The provision of water for the environment on the Namoi River has solely relied on unregulated/supplementary flows and restrictions on access to these flows for irrigation pumping. These rules were first implemented with the 1998 Namoi River Flow Rules and were subsequently formalised under the Water Sharing Plan for the Upper Namoi and Lower Namoi Regulated River Water Sources (see section 1.5.1). As such there is no history of using held water for environmental outcomes. Similarly, on the Namoi River there is no existing governance framework for advice and decision-making on the use of held environmental water as exists on other river systems such as the Gwydir and Macquarie Rivers, and no held planned environmental water under the Water Sharing Plan.

Section 8E (7) of the Water Management Act requires that water access licenses proposed for use as adaptive environmental water are to have suitable conditions applied. To meet these conditions, NSW RiverBank has prepared Water Use Plans for river systems where they hold entitlements. There are no water use plans for adaptive environmental water in the Namoi River.

The use of held environmental water will require ‘water orders` to be placed with the NSW State Water Corporation to trigger dam releases. Some possible locations for accounting of water orders have been included in this document (see section 6.2), however accounting points will need to be negotiated with State Water, considering the location of environmental watering points (C Cahill (State Water) 2011, pers. comm., 26 August). An example of this is if environmental water is delivered with an objective of wetting benches below Narrabri, then it is likely the Narrabri gauge would be used as the accounting point.

1.5 Water Sharing Plan provisions for environmental water

1.5.1 The Water Sharing Plan for the Upper Namoi and Lower Namoi Regulated River Water Sources

The Water Sharing Plan (WSP) for the Upper Namoi and Lower Namoi Regulated River Water Sources commenced in July 2004 and will apply for 10 years until 30 June 2014. The upper Namoi includes the regulated river sections between Split Rock and Keepit Dams. The lower Namoi includes the regulated river sections downstream of Keepit Dam to the Barwon River, including the regulated sections of the Gunidgera/Pian Creeks system (the latter terminates at Dundee Weir) (DLWC 2003, NRRMC 2001).

The plan sets a long-term extraction limit of 238,000 megalitres per year for the Namoi River, above which all flows are protected for the environment. This limit aims to ensure that approximately 73 per cent of the long-term average annual flow in these water sources is protected for environmental health (DIPNR 2004).

Under this WSP the major environmental provisions for the regulated Namoi water source are:

- All flows above the long-term average extraction limit are reserved for the environment.
- Minimum flows of 21 ML/d in June, 24 ML/d in July and 17 ML/d in August are targeted at Walgett when Split Rock and Keepit dams hold more than 120 gigalitres.
- The volume of water that may be made available for extraction under supplementary water access licences during a supplementary water event may not exceed 10 per cent of the supplementary event volume for events occurring between 1 July and 31 October, and 50 per cent of the supplementary event volume for events between 1 November and 30 June.
- The limits to supplementary water access licences in the lower Namoi also provide environmental benefits by protecting water level rises, maintaining inundation and flow variability.

These environmental flows rules were established to:

- ensure there is no erosion of the long-term average volume of water available to the environment during the life of the plan
- maintain flows in the lower reaches of the river, which have been significantly affected by river regulation and extraction, to ensure that flows in these reaches are more reflective of the natural flow patterns
- restrict access to high flows in order to protect important rises in water levels, maintain wetland and floodplain inundation and retain natural flow variability
- contribute to maintenance of water quality in the water sources included in the Water Sharing Plan.

Extraction of water under supplementary water access licences is only permitted in accordance with announcements made by the NSW Office of Water. These announcements specify when water can be taken and the maximum volume that may be taken over the period. Extractions are only permitted:

- from unregulated flows
- when flows are in excess of those required to provide specified replenishment flows
- when flows are in excess of those needed to meet the requirements of the Interim Unregulated Flow Management Plan for the North West
- when flows are in excess of the thresholds specified in the WSP[1].

1 These thresholds vary depending on river sections, time of year and the volume of water in general security accounts, details are available from the Water Sharing Plan.

The WSP also provides for the supply of water to towns, riparian landholders, irrigation and other industry for the benefit of rural communities in the Namoi River system. In order to meet these objectives, replenishment flows are managed by State Water according to the rules outlined in the plan.

Replenishment flows, as defined in the WSP, are "flows provided to refill pools and water holes in effluent river systems downstream of the water source and provide water for household and town use and stock". While this water is not strictly identified as 'environmental water' (planned environmental water or held environmental water), benefits to environmental values may accrue and improved delivery efficiency can be achieved when operational flows and environmental flows are managed in concert with each other.

1.5.2 Peel Regulated, Unregulated, Alluvial and Fractured Rock Water Sources

The Water Sharing Plan for the Peel Regulated, Unregulated, Alluvial and Fractured Rock Water Sources commenced on 1 July 2010 and applies until 30 June 2020. The plan recognises that the water resources of the Peel Valley are interlinked and would therefore benefit from being managed collectively (NOW 2010). The plan includes extraction of all surface water connected alluvial and fractured rock aquifers in the Peel Valley.

The current environmental water rules (see Appendix 1) require a 'stimulus flow' of up to 1,600 megalitres to be provided if the Chaffey storage exceeds 50,000 megalitres at the start of the water year. The purpose of a stimulus flow is to achieve environmental benefits by stimulating the ecosystems downstream of the dam. There are also provisions for a stimulus flow if the storage is less than 50,000 megalitres at the start of the water year (see section 8.5 and Appendix 1). The plan also has rules for when Chaffey Dam is enlarged which involves the creation of up to a 5,000 megalitres of environmental contingency allowance (see Appendix 1).

1.5.3 Other Water Sharing Plans

There are other Water Sharing Plans for the Namoi catchment but they are of less relevance to this environmental water delivery document. These plans are explained below.

Phillips Creek, Mooki River, Quirindi Creek and Warrah Creek Water Sources

The Water Sharing Plan for the Phillips Creek, Mooki River, Quirindi Creek and Warrah Creek Water Sources commenced in July 2004 and applies until 30 June 2014. These water sources are unregulated tributaries which enter the regulated reach of the Namoi River through the Mooki River upstream of Gunnedah. The water sources are ephemeral and highly variable, and the development of these catchments has resulted in alterations to natural river flows through the extraction of water for irrigation and domestic and stock purposes.

Upper and Lower Namoi Groundwater Sources

The Water Sharing Plan for the Upper and Lower Namoi Groundwater Sources establishes extraction limits for each groundwater source for a 10-year period from its commencement in November 2006. The plan covers three categories of groundwater access licences: Local Water Utility Access Licences, Aquifer Access Licences and Supplementary Water Access Licences. The Local Water Utility Access Licences are held by local government and are for town water supply purposes. The plan provides for a total of 4,407 megalitres for town water supply in the lower Namoi and 6,787 megalitres in the upper Namoi groundwater source.

NSW Great Artesian Basin Water Sources

The Water Sharing Plan for the NSW Great Artesian Basin (GAB) Water Sources commenced on 1 July 2008 and will apply for a period of 10 years. The Great Artesian Basin underlies the western half of the Namoi catchment. The plan covers all water contained in the sandstone aquifers of the NSW portion of the GAB.

1.6 Flow characteristics

An indication of the impact of development on the flow regime of the Namoi River can be seen by assessing the flow duration curves at the sites of Boggabri, Wee Waa and Walgett. These are presented in Figure 2 to Figure 4 for pre-development and current conditions. Flow information for both the pre-development regime and the current regime have been made available by the NSW Office of Water (NOW). As can be seen from the figures, for all but very low flows, the flow regime under current development is lower than that under pre-development. While the graphs would seem to indicate the alteration in daily flows is small, the change in annual flow volumes is significant in some locations. For example, at Wee Waa average annual flows have been reduced by over 20 per cent. Differences in flow volume alterations at Boggabri which is upstream of the majority of irrigation is considerably less at approximately 5 per cent.

For much of the time, flows under both pre and current development are very small, with large flows (such as greater than 5,000 ML/d) only being experienced in 10 per cent or less of the time.

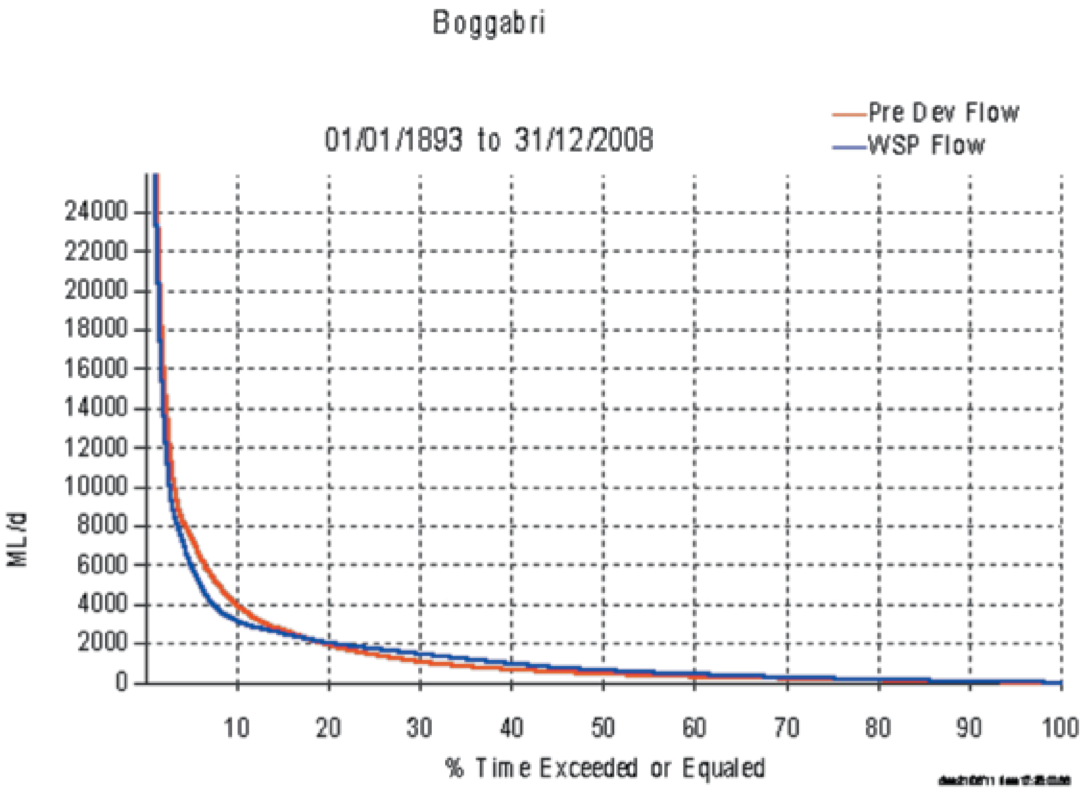

Figure 2: Namoi River at Boggabri flow duration curve (NSW Office of Water IQQM)

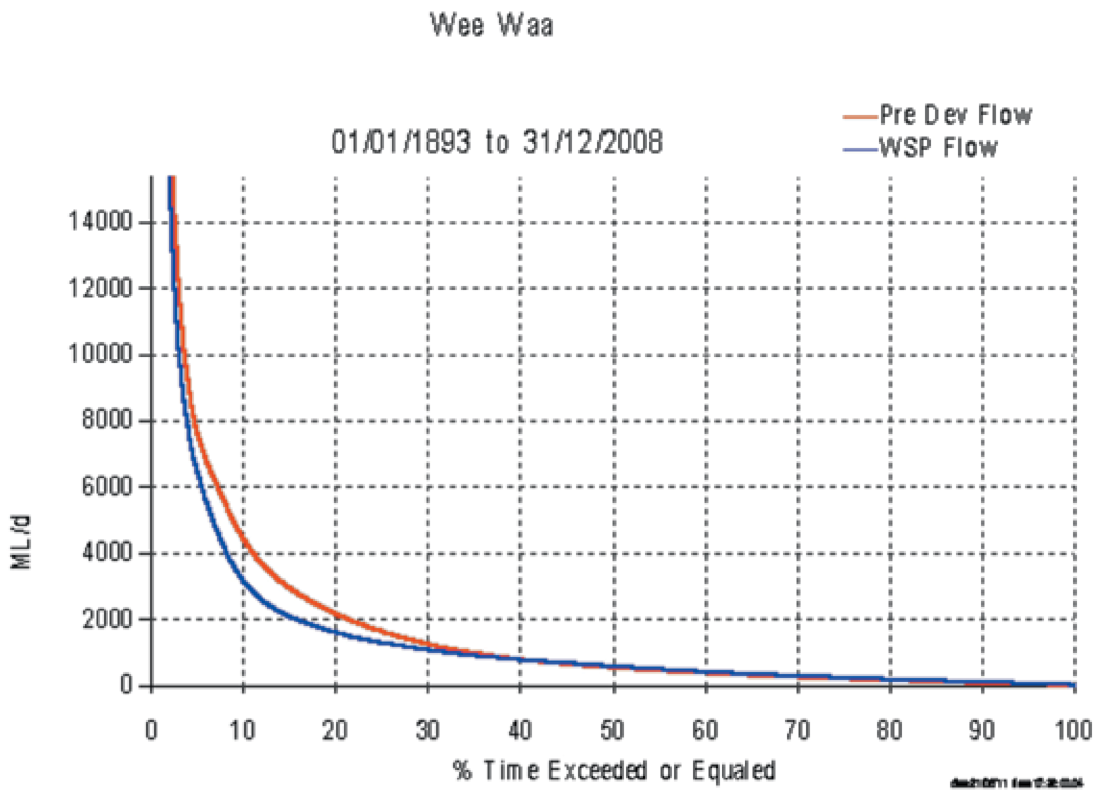

Figure 3: Namoi River at Wee Waa flow duration curve (NSW Office of Water IQQM)

Figure 4: Namoi River at Walgett flow duration curve (NSW Office of Water IQQM)

The alteration of seasonality and monthly magnitude of mid-catchment and end-of-system flows is shown in Figure 5 and Figure 6 respectively (CSIRO 2007). This shows that whilst seasonality has been maintained despite development upstream there has been an overall reduction in flows across all months from pre-development.

For example, prior to development of the Namoi River, end of system cease to flow periods were likely to occur around 5 per cent of the time. Following river regulation, the frequency of cease to flow periods at the end of the system has increased to 13 per cent of the time (CSIRO 2007).

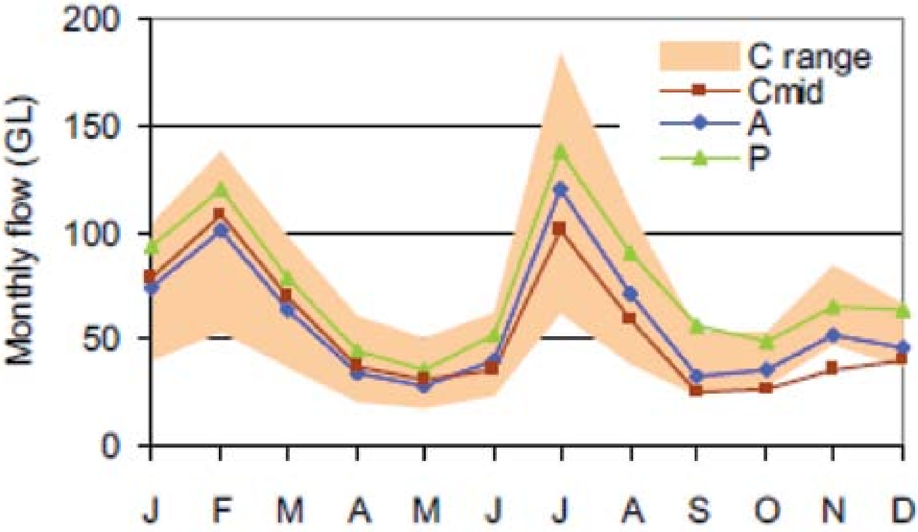

Figure 5: Combined Bugilbone and Pian Creek seasonal flow curves under pre-development scenarios (P), Current Development Scenario (A), and middle (Cmid) Climate Change Scenario (CSIRO 2007)

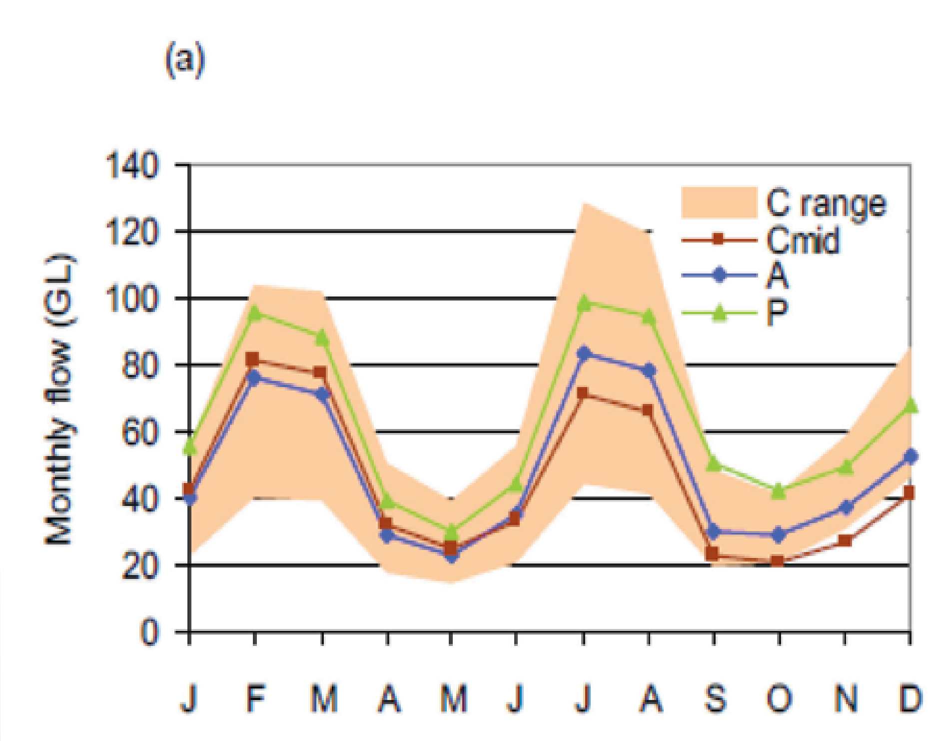

Figure 6: End of system seasonal flow curves under pre-development scenarios (P), Current Development Scenario (A), and middle (Cmid) Climate Change Scenario (CSIRO 2007)

1.7 Irrigation demand

The distribution of land uses in the Namoi catchment is shown in Figure 7. Over half of the catchment area is used for dryland agriculture. The floodplains of the lower valley consist of heavy black and grey clays that are well-suited to irrigated agriculture. Irrigation development has occurred quite rapidly since the early 1960's and up to 112,400 hectares is now used to grow crops such as cotton, cereals and horticulture (CSIRO 2007).

Current levels of extraction are governed by the long-term extraction limit (LTEL) and the Murray-Darling Basin Cap, with the maximum volume that may be taken from a general security access licence in a single year in the Lower Namoi equivalent to 1.25 megalitres per unit share[2]. Extraction in any one year is likely to be above or below the LTEL, however, if extraction is shown to be in excess of the LTEL or Cap, restrictions on allocations and hence extractions are put in place (refer section 8.3 for complete water use limitations as outlined in the Water Sharing Plan). To date, there has been no Cap breach action taken in the Namoi catchment and all LTELs on NSW Murray-Darling Basin rivers are below the cap limit.

Water usage in the valley is for riparian[3], stock and domestic and agricultural use and is available from both the surface and groundwater resource (Kelly et al. 2007). Usage is either from pumping or gravity-fed surface water, extraction from groundwater bores or through the taking of surface water from flows travelling across the floodplains (floodplain harvesting). Only regulated river surface water and groundwater usage is metered. Usage for riparian purposes, floodplain harvesting, and unregulated usage is currently not metered.

The region uses 2.6 per cent of the surface water diverted for irrigation in the Murray-Darling Basin, while the groundwater resources of the region are the most intensively developed in NSW (CSIRO 2007). An average daily flow of 1,922 megalitres is maintained in the Namoi River at Gunnedah, downstream flows decrease to around 1,500 megalitres per day due to the significant irrigation extractions and diversions into effluent channels (Green et al. 2011). Apart from Keepit and Split Rock Dams delivering water for irrigation purposes, major irrigation diversions are also made from Mollee and Gunidgera Weirs.

Chaffey Dam, on the Peel River, supplies town water, stock and domestic, irrigation and environmental flows. The dam provides water supplies and drought security to Tamworth and significant irrigation along the Peel Valley, used for the production of cotton, wheat, lucerne, vegetables, fruit trees, oil seeds and fodder as well as pastures for sheep and cattle (State Water 2009). There are 192 licences with 48,292 megalitres of entitlement including high-security/industry entitlements of 804 megalitres, general-security entitlements of 30,900 megalitres, stock and domestic requirements of 177 megalitres and town water supplies of 16,400 megalitres (State Water 2009).

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2 The LTEL is set at the volume of extraction that existed in 1999/2000, the share components existing at the commencement of the plan and the application of the water management rules defined in the plan. Compliance with the limit is determined using the IQQM for the Upper Namoi and Lower Namoi Regulated Rivers. If this indicates that LTEL from these water sources, plus 95 per cent of the growth in extractions by Tamworth City Council, are in excess of the limit then the volume of water made available to supplementary water access licences will be reduced until extraction returns to the limit.

3 There are specific riparian water use high-security access licences which allow for irrigation of up to 2 hectares for domestic gardens. These extractions are not metered as the associated volumes are quite small when compared to large-scale irrigation extraction.

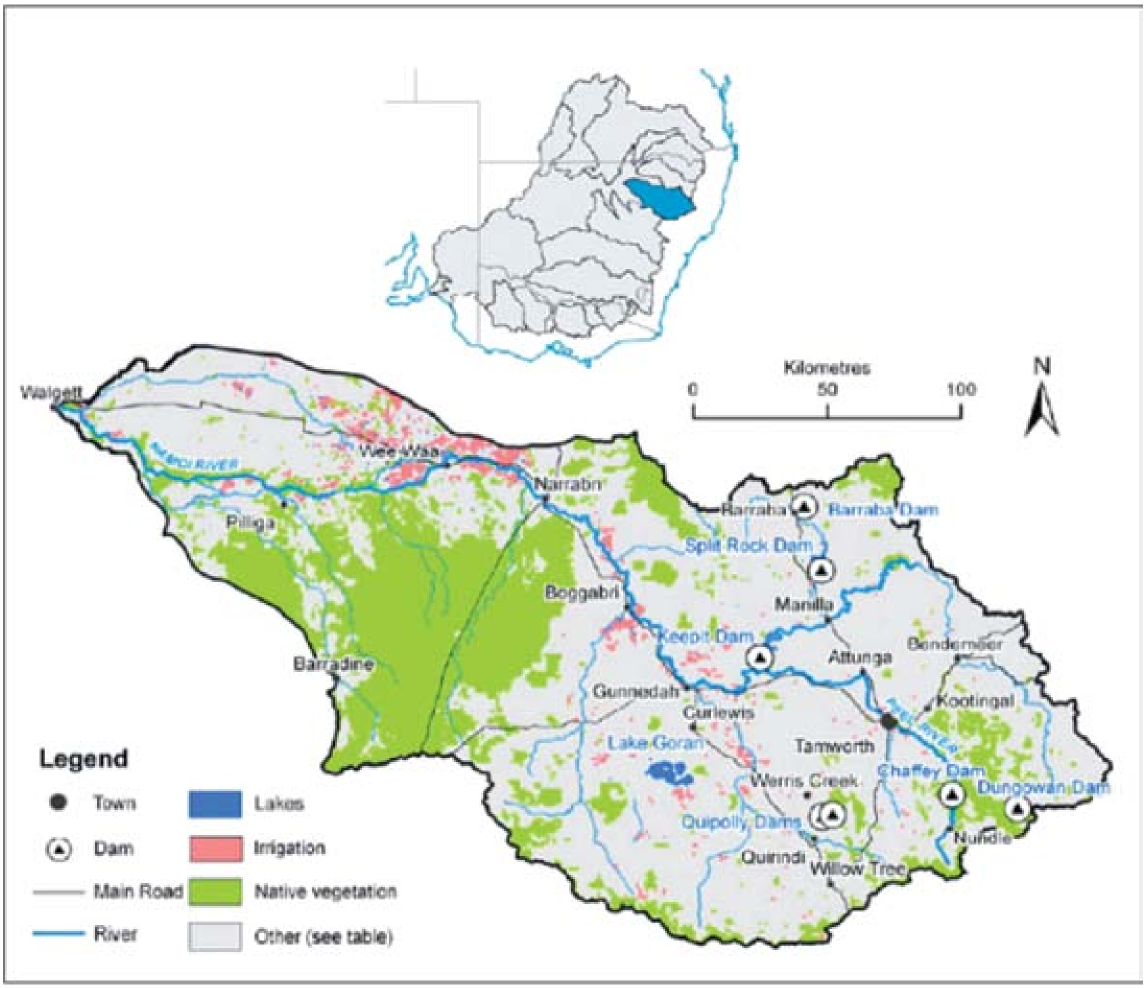

Figure 7: Land uses of the Namoi catchment (CSIRO 2007)

The major water users in the Namoi catchment are general-security licence holders with a total annual entitlement of 254,976 megalitres of which 9,724 megalitres is located on the upper Namoi between Split Rock and Keepit Dams.

Total share components for all users issued for the regulated Namoi River total nearly 379,000 megalitres as per the following, inclusive of both the upper and lower sections (Green et al. 2011):

- domestic and stock—1,821 megalitres
- domestic and stock (stock)—263 megalitres
- domestic and stock (domestic)—28 megalitres
- local water utility—2,421 megalitres
- general security—245,946 megalitres
- high security—3,498 megalitres
- high security (research)—486 megalitres
- supplementary—115,469 megalitres.

Supplementary water access is declared according to the Water Sharing Plan rules so that water users can divert water from the river without debit to their water account. There is a total licensed supplementary cap of 110,000 megalitres per year with all supplementary licences being located in the lower Namoi.

1.8 Flow monitoring sites

There is a large number of flow monitoring stations along the regulated Namoi River. The NSW Office of Water's real-time website provides information on the sites on the Namoi and also a wide range of flow data and water quality information: http://realtimedata.water.nsw.gov.au/water.stm.

1.9 Hydrology modelling

The NSW Office of Water's Namoi Integrated Quantity and Quality Model (IQQM) is used to represent flow relationships and evaluate water-planning decisions for the regulated section of the Namoi River. The model can be used for a wide range of scenarios for different water sharing and distribution arrangements and has been used in this document for assessing the impact of development on flows and forecasting account volumes for different categories of licenses.

2. Ecological values, processes and objectives

2.1 Summary of ecosystem values for the Namoi River

The aquatic and terrestrial environments of the Namoi catchment provide habitat for a number of threatened species and ecological communities that are protected under the *Threatened Species Conservation Act 1995* (NSW) and the *Environment Protection and Biodiversity Conservation Act 1999* (Cwlth) (EPBC Act). The Namoi has been included as part of the endangered aquatic ecological community in the natural drainage system of the lowland catchment of the Darling River, under the *Fisheries Management Act* (NSW) (NSW Scientific Committee 2004). The community is known to occur in lowland riverine environments with meandering channels and a variety of aquatic habitats including deep channels and pools, wetlands, gravel beds and floodplains (Green et al. 2011). Four aquatic fauna species which are known to occur within the Namoi catchment are listed as endangered under the *Fisheries Management Act 1994* (NSW): the river snail (which has recently been found in the Pilliga region), freshwater catfish, purple spotted gudgeon, and the olive perchlet. Other species of significance include the silver perch which is listed as vulnerable in NSW, and Murray cod which is listed as vulnerable under the EPBC Act (refer to Appendix 2).

The Namoi catchment supports a number of species protected under state and federal legislation. This includes 28 threatened plant species, with 11 of these being listed as endangered, and 66 threatened fauna species that include four species of amphibians, nine bats, 37 birds, 11 mammals and five reptiles (Green et al. 2011). Threatened species associated with riverine environments have been listed in Appendix 2.

Within the Namoi catchment, Lake Goran is a nationally significant large wetland complex listed under *A Directory of Important Wetlands of Australia* (Environment Australia 2001). The lake is land locked, and as such cannot benefit from environmental watering. The floodplain downstream of Narrabri supports many small lagoons, wetlands, and anabranches, as well as flood runners and extensive areas of floodplain woodlands. Six broad vegetation communities have been associated with the lower Namoi floodplain (Cotton Catchment Communities CRC 2009) and include:

- carbeen woodlands on flats and gentle slopes, often associated with ancient watercourses
- riparian woodland (Coolibah in association with river red gum or black box) on frequently flooded areas of the floodplain
- coolibah or black box woodland on higher areas of the floodplain

- bimble box woodland on elevated floodplains and ridges
- river red gum forest and woodland along riverbanks and river flats
- weeping myall on flats or gentle rises that are above inundation.

Native vegetation communities within the Namoi catchment are known to be generally degraded and are protected under the *Native Vegetation Act 2003* (NSW). The endangered ecological community coolibah-black box woodland (protected under the EPBC Act) has been extensively cleared for cropping or modified by grazing and is now at around two-thirds of its original extent within NSW. Other floodplain vegetation communities include river red gum (*Eucalyptus camaldulensis*), which is also supported along the Peel River; river cooba (*Acacia stenophylla*); and cooba (*Acacia salicina)*, which grows along major watercourses on the slopes and plains and floodplains that receive sufficient flooding for an extended period. The floodplain complex of coolibah (*E. coolabah*), black box (*E. largiflorens*) and lignum (*Muehlenbeckia florulenta*) also requires frequent flooding and may be subject to occasional prolonged inundation.

The Peel River, as part of the Namoi catchment, supports various sedges, rushes and reeds in-stream. Riparian vegetation includes river oaks (*Casuarina cunninghamiana*,) rough-barked apple (*Angophora floribunda*), river red gum, *Callitris sp.*, and *Lomandra sp.* Associated waterbirds include straw-necked ibis (*Threskiornis molucca*), often observed on floodplain areas. The area downstream of the confluence of the Cockburn River is characterised by a well-formed floodplain and the formation of an anabranch system directly downstream of Tamworth. The unregulated Peel Anabranch is highly degraded due to long-term gravel extraction operations.

Eco Logical Australia (2008) mapped a total of 2,766 wetlands in the valley totalling 46,398 hectares. Of these, 1,829 were identified as natural wetlands and 937 were artificial wetlands (dams, weir pools and other storages). Notable Namoi wetlands include Barbers Lagoon and Gulligal Lagoon.

Barbers Lagoon, which has been studied under the Integrated Monitoring of Environmental Flows program (IMEF), is a wetland site located near Boggabri on a travelling stock reserve. It consists of a straight, deep channel which retains water for long periods. Both banks support river red gums, and Warrego summer grass (*Paspalidium jubiflorum*) dominates the higher bank areas with water couch (*Paspalum distichum*) found on the water's edge. As water recedes there is minimal colonisation by plants, apart from weed species. Aquatic macrophytes have not been recorded in the deeper water areas (W Mawhinney (NOW), 2011, pers. comm.).

The Namoi River channel provides important habitat for aquatic species and connectivity with the Barwon-Darling River. In-channel habitats include important geomorphic features such as river benches. These benches are sites for the contribution of organic carbon to the aquatic system which provides energy sources for food production for many aquatic species (NRRMC 2001).

The river downstream of Keepit Dam (the lower Namoi) has been described in four geomorphic zones by Thoms et al. (1999) (Table 1). Immediately downstream of Keepit and the Peel River tributary confluence is a mobile zone linking into a meander zone to just upstream of Boggabri. From Boggabri to Wee Waa is an anabranching zone while Pian Creek and Namoi River downstream is primarily a distributary zone.

Lampert and Short (2004) provide a detailed assessment of the river styles and condition of the Namoi catchment. Classifications and condition of the Namoi catchment provided from this assessment are summarised in Appendix 3.

Table 1: Ecological values of geomorphic zones of the Namoi and Peel rivers

Zone	Characteristics of zone	Ecological values and habitat
Mobile	Very active channel and bed sediments, sediment transfer area.	Sandy gravel deposits are important habitat.
Meander	Active channel with common bank erosion.	Benches Meander cutoff channels Floodplain connectivity
Anabranch	Relatively stable, multi channels during floods.	Billabongs, anabranches Floodplain connectivity Benches
Distributary	Multi-channelled.	Floodplain connectivity Billabongs, anabranches Benches

Source: Thoms 1998.

For all of the zones presented in Table 1 there are three important features that can be linked to specific commence-to-flow ranges (provided in section 5):

- Within bank benches: these features are important for organic matter transfer and are generally wetted at relatively low within-bank flows. They may also be important riparian zones.
- Cutoff channels and small billabongs are a feature of the lower Namoi River and may connect to the river at different commence-to-flow values. Once the commence-to-flow is reached, the billabong will fill and may flush, with a pool left behind after the flows recede providing habitat for some months.
- There is a riparian/floodplain strip along much of the lower Namoi River; a considerable portion of this is managed as Crown land stock reserve and is heavily grazed. This area generally requires higher flows and out-of-channel flows to fully inundate. There is also likely to be some interaction with channel flows and bench and billabong inundation.

Other important features of the lower Namoi River are the anabranches which can take a considerable proportion of the flow. An example of this is Duncans Warrambool, located near Pilliga where the Namoi River splits in two for a distance of 6 kilometres. The northern channel, known as Duncans Warrambool, carries two-thirds of the flow. There are also a number of ephemeral watercourses that flow westward across the lower Namoi floodplain, including Drildool, Cubbaroo, Dead Bullock and Chambers Warrambools.

Lake Keepit supports one of NSW's most important recreational fisheries. Native species present included golden perch (*Macquaria ambigua)*, freshwater catfish (*Tandanus tandanus)*, Murray cod (*Maccullochella peelii*) and silver perch (*Bidyanus bidyanus*) (Battaglene & Callanan 1991). During the mid-1980's Lake Keepit also supported a diverse and abundant waterbird population. A study between 1982 and 1985 revealed 38 waterbird species using the lake, often in large numbers (Wettin unpublished and cited in Green & Dunkerley 1992). Birds feeding on fish and invertebrates dominated the waterbird community but duck species were also common. Species observed in large numbers (greater than 1000 individuals) were black duck (*Anas superciliosa)*, grey teal (*Anas gracilis*), wood duck (*Chenonetta jubata*), Australian pelican (*Pelecanus conspicillatus*), little black cormorant (*Phalacrocorax sulcirostris*), great crested grebe (*Podiceps cristatus*), Eurasian coot (*Fulica atra*) and silver gull (*Chroicocephalus novaehollandiae*). Over the period of the study 11 species of waterbird were observed breeding.

The Namoi River is very important to the flows in the Barwon-Darling River, contributing on average some 30 per cent of the flow of the Darling River upstream of Bourke under current development conditions (Webb, McKeown & Associates 2007a,b). The importance of this contribution is recognised in the Water Sharing Plan which has placed limits to lower Namoi supplementary water access when flows are needed to meet the requirements of the Interim Unregulated Flow Management Plan for the North West. The latter interim plan has flow requirements for the Barwon-Darling River to reduce the incidence of blue-green algal blooms in weir pools and to provide weir drown-outs to permit greater fish passage.

2.2 Ecological objectives

There are a range of ecological objectives which have been developed to guide environmental water use in the Namoi River. The following section outlines the pre-existing ecological objectives that have been used as the basis for the development of ecological and water-delivery objectives for the assets/water-management areas of the Namoi River.

System-wide objectives

For the purpose of this document, the following system-wide objectives are being adopted to guide environmental water use:

- reduce duration of time between flow events
- provide for a natural drying cycle in channels and wetlands
- provide in-channel drought refuge for native fish species and waterbirds
- support wetland vegetation and waterbird breeding
- improve hydrologic connectivity between river channel and floodplain
- increase hydrological variability through increased flow volumes in high flow events and freshes.

2.2.1 Environmental watering objectives to meet ecological objectives under a range of climate scenarios

The Department of Sustainability, Environment, Water, Population and Communities has outlined a number of key ecological and management objectives under different water availability scenarios (Table 2). These objectives take into account climate variability and the required change in aims and actions governed by the amount of water available.

Table 2: Ecological and management objectives for environmental water use under different water-resource availability scenarios

	Extreme dry	Dry	Median	Wet
Ecological watering 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.
Management objectives	• Avoid critical loss of threatened species and communities. • Maintain key refuges. • Avoid irretrievable damage or catastrophic events.	• Support the survival and growth of threatened species and communities including limited small-scale recruitment. • Maintain diverse habitats. • Maintain low-flow river and floodplain functional processes in sites and reaches of priority assets.	• Enable growth, reproduction and small-scale recruitment for a diverse range of flora and fauna. • Promote low-lying floodplain-river connectivity. • Support medium-flow river and floodplain functional processes.	• Enable growth, reproduction and large-scale recruitment for a diverse range of flora and fauna. • Promote higher floodplain-river connectivity. • Support high-flow river and floodplain functional processes.
Management actions	• Water refugia and sites supporting threatened species and communities. • Undertake emergency watering at specific sites of priority assets. • Use carryover volumes to maintain critical needs.	• Water refugia and sites supporting threatened species and communities. • Provide low-flow and freshes in sites and reaches of priority assets. • Use carryover volumes to maintain follow-up watering.	• Prolong inundation/ high-flow duration at key sites and reaches of priority assets. • Contribute to the full-range of in-channel flows. • Use carryover to provide optimal seasonal flow patterns in subsequent years.	• Increase flood/ high-flow duration and extent across priority assets. • Contribute to the full range of flows including over-bank. • Use carry over to provide optimal seasonal flow patterns in subsequent years.
	Damage avoidance	*Capacity for recovery*	*Maintained health and resilience*	*Improved health and resilience*

Source: DEWHA 2009.

2.2.2 River system-wide objectives

There are also a number of pre-existing river system-wide objectives related to environmental outcomes for the Namoi catchment.

Murray-Darling Basin Authority

The Murray-Darling Basin Authority (MDBA) have identified the Namoi River to be a key environmental asset for the Namoi Region, with five hydrological indicator sites for key ecosystem functions being listed, namely:

- Peel River downstream of Chaffey Dam
- Peel River at Piallamore
- Namoi River downstream of Keepit Dam
- Namoi River at Mollee
- Namoi River at Goangra.

The following broad objectives have been established by the MDBA for hydrologic indicator sites:

- creation and maintenance of habitats for use by plants and animals
- transportation and dilution of nutrients, organic matter and sediment
- provision of connections along the river and downstream for migration and recolonisation by plants and animals
- provision of connections across floodplains, adjacent wetlands and billabongs for foraging, migration and recolonisation by plants and animals.

The Namoi River Water Sharing Plan

The Water Sharing Plan rules (DIPNR 2004) limit total extractions from lower Namoi supplementary water during periods when flows are above specified thresholds. These include uncontrolled flows, flows in excess of those required for replenishment flows, flows greater than those needed to meet the North-West Interim Unregulated Flow Management Plan[4] and flows in excess of the thresholds specified in the Water Sharing Plan. These rules contribute to the following interim river flow objectives[5]:

- protecting important rises in water levels
- maintaining wetland and floodplain inundation
- maintaining natural flow variability.

The Namoi Catchment Action Plan

The Draft 2011–2020 Catchment Action Plan, recently developed by the Namoi Catchment Management Authority, provides strategic direction for natural resource management within the Namoi catchment. The latest plan uses a 'resilience thinking' approach to determine important thresholds in the catchment and actions required to prevent progression below these thresholds.

Water critical thresholds developed in the draft Catchment Action Plan include:

- surface water flow, including quantity, is at 66 per cent of natural (pre-development) condition with a sensitivity to natural frequency and duration
- geomorphic condition is good (against benchmark condition)
- recruitment of riparian vegetation is higher than attrition of individual trees, shrubs or groundcover species
- agricultural and urban supply aquifers do not cross into lower levels of beneficial use regarding quality
- alluvial aquifers are not drawn down below long-term historical maximum drawdown levels
- groundwater is within 30 metres of surface where there are identified groundwater-dependent ecosystems
- wetlands are not drained, dammed or otherwise physically modified.

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4 The Namoi River is one of a number of Barwon-Darling tributary rivers covered by the North-West Interim Unregulated Flow Management Plan. This plan was developed in 1992 to introduce targets in the Barwon-Darling for riparian, algal suppression and fish-migration flows to take precedence over normal license conditions when required by the then NSW Department of Water Resources. Flow targets in the Barwon-Darling specified under the plan may, at times, be met by flows coming from other rivers or may require contributions of flow from tributary rivers such as the Namoi.

5 The interim river flow objectives were determined in the late 1990's as part of a statewide process by the then NSW Environment Protection Authority. The OEH has current information http://www.environment.nsw.gov.au/ieo/index.htm.

Catchment water targets related to preventing progression below the water critical thresholds include:

- Catchment Water Target 1—by 2020 there is an improvement in the condition of those riverine ecosystems that have not crossed defined geomorphic thresholds as at the 2010 baseline.
- Catchment Water Target 3—by 2020 there is an improvement in the condition of regionally important wetlands and the extent of those wetlands is maintained.

The river reach between Boggabri and Narrabri has also been established as a demonstration reach under the Native Fish Strategy (see Appendix 3 for details). A state government initiative, the 120-kilometre demonstration reach has resulted in the modification or removal of 16 priority fish barriers and the improved management of riparian land (DPI 2006).

Additionally, there has been a study focussing on the improved management of irrigation off-takes to reduce adverse impacts on native fish.

2.2.3 Broad-scale system objectives for the use of environmental water

Broad-scale system objectives for the use of environmental water in the Namoi catchment are described in Table 3. The objectives seek to provide guidance as to how water should be used under different climatic and flow conditions and often in conjunction with other water reserves to meet ecological objectives related to Namoi environmental assets. These objectives are incorporated into the delivery scenario objectives presented in section 3.2.

Table 3: Broad-scale system and asset ecological objectives for targeted environmental water use in the Namoi catchment

Broad-scale system objective	Water management area	Asset ecological objectives
Provide **baseflows** to avoid damage to ecological assets. This will reduce the duration of time between flow events and provide in-channel drought refuge for native fish and waterbirds in order to: • avoid critical loss of threatened species and communities • maintain key refuges • avoid irretrievable damage or catastrophic events.	Permanent regulated river section (Regulated Namoi and Peel rivers).	Maintain in-stream refuges and aquatic habitat for native fish species along the river channel. Prevent fish stranding and allow the completion of critical life cycle processes such as spawning, seed setting and dormant stages along the river channel and in Pian Creek. Promote productivity to maintain food webs and ecosystem function for in-channel flora and fauna. Maintain water quality within channels and pools. Prevent stratification in deep pools.
Provide **minor inflows** to ensure ecological capacity for recovery. This will support wetland vegetation and native fish spawning, as well as improve hydrologic connectivity between river channel and floodplain in order to: • support the survival and growth of threatened species and communities • maintain diverse habitats • maintain low-flow river and floodplain functional processes.	Riverine assets with low commence-to-flow or structures for water delivery (e.g. low commence-to-flow benches and point bars in all reaches and Duncans Warrambool).	Provide habitat for native fish species through wetting of low-level point bars and the riparian zone to provide connectivity between river channel and low-elevation floodplain wetlands. Inundate low-level benches to promote species diversity. Establish and maintain native water plants for improved water quality and wetland habitat in anabranches between Mollee Weir and Gunidgera Weir and in Duncans Warrambool. Support in-channel geomorphic structure and organic matter inputs in the river channel and anabranches. Contribute to the ecological requirements of the Barwon-Darling River through increased end-of-system flows in the river channel between Wee Waa and Walgett.

Broad-scale system objective	Water management area	Asset ecological objectives
Provide **medium inflows** to maintain ecological health and resilience. This will increase hydrological variability through increased flow volumes in floods and freshes, improve hydrologic connectivity between river channel and floodplain and support wetland vegetation and waterbird breeding in order to: • enable growth, reproduction and small-scale recruitment of a diverse range of flora and fauna • support medium-flow river and floodplain functional processes.	End of system at Walgett. Provide full bank flow to the Namoi River channel; inundate wetlands. Piggyback on end-of-system flows; medium commence-to-flow anabranches/warrambools (e.g. Barbers Lagoon and point bars).	Using pulsed flows, inundate low commence-to-flow riparian wetlands and mid-level benches along the river channel and anabranches to support riparian vegetation condition. Provide wetting of medium-level benches along the river channel and anabranches to promote connectivity with riparian assets and adjacent floodplain. Provide pulsed freshes to trigger native fish spawning (e.g. silver perch, golden perch and Murray cod) in river channel, Narrabri Creek, Pian Creek and Barbers Lagoon. Maintain water quality and support in-channel geomorphic structure and organic matter inputs in the river channel and anabranches. Provide nesting and foraging habitat for waterbirds such as ibis, freckled duck, blue-billed duck, egrets and herons in anabranches, Barbers Lagoon and Duncans Warrambool. Contribute to the ecological requirements through piggybacking on baseflow and freshes of the Barwon-Darling through increased end-of-system flows in the river channel between Wee Waa and Walgett. Provide adequate wetting to support river red gum, black box, river cooba and coolibah communities associated with channel and low commence-to-flow habitats.
Provide **high inflows** to improve and extend healthy and resilient aquatic ecosystems. This will increase hydrological variability through increased flow volumes in high flows and freshes, improve hydrologic connectivity between river channel and floodplain and support wetland vegetation and waterbird breeding in order to: • enable growth, reproduction and small-scale recruitment of a diverse range of flora and fauna • support high-flow river and floodplain functional processes.	End-of-system flows at Walgett. Inundate wetlands requiring greater volumes and high commence-to-flow. Support end-of-system flows and higher commence-to-flow warrambools and lagoons including backwaters.	Using pulsed flows, inundate higher commence-to-flow riparian wetlands and mid-level benches along the river channel and anabranches to support riparian vegetation condition and promote productivity. Provide wetting of high-level benches along the river channel and anabranches to promote connectivity with riparian assets and adjacent floodplain and productivity. Support condition of river red gum, black box, coolibah and river cooba communities along the river channel and anabranches by increasing connectivity between floodplain and river channel and by providing adequate inundation flows to lagoons. Maintain water quality and support in-channel geomorphic structure and organic matter inputs in the river channel and anabranches. Maintain open water areas by providing adequate inundation flows to lagoons (e.g. Barbers Lagoon). Provide nesting and foraging habitat for waterbirds such as ibis, freckled duck, blue-billed duck, egrets and herons in anabranches, Barbers Lagoon and Duncans Warrambool. Contribute to the ecological requirements through piggybacking on baseflow and freshes of the Barwon-Darling through increased end-of-system flows in the river channel between Wee Waa and Walgett.

3. Watering objectives for water-dependent assets

3.1 Asset environmental watering objectives

There are several key considerations involved in developing the asset watering objectives. Consideration has been given to the climate sequence scenarios and broad-scale system objectives (Tables 2 and 3) in developing the environmental watering objectives for each asset or water-management area (WMA). Under each climate scenario different volumes of environmental water would be available and therefore will be able to achieve correspondingly more or less environmental watering outcomes.

In reality, the climate scenarios are part of a constant continuum and only the current circumstances can be assessed in relation to the past few years to determine which scenario applies. Forecasting the future climate scenario is currently problematic although short-term probabilities are provided by the Bureau of Meteorology.

3.2 Development of ecological and watering objectives for Namoi assets and water management areas

The general system-wide objectives used for developing the asset watering objectives in Table 4 for each climate scenario are to:

- reduce duration of time between flow events
- provide for a natural drying cycle
- provide drought refuge for native fish species and waterbirds
- support wetland vegetation and waterbird breeding
- improve hydrologic connectivity between channel and floodplain
- increase hydrological variability through increased flow volumes in floods and freshes.

The ecological and watering objectives provided in Table 4 have been developed using available reports and additional analysis. Appendix 3 provides more details for each asset/WMA. Most of the reports have identified commence-to-fill levels for in-channel benches and billabongs, namely from Foster (1999, 2004). No previous report has identified the specific environmental flow requirements for these features or in-channel habitats, particularly in terms of the required duration and seasonality. Consequently, professional judgement has been used to determine the water requirements for these objectives (Table 10). It has also been assumed that irrigation and other consumptive water orders, particularly from September to February, will meet the environmental water requirements for in-channel assets.

As indicated above, the environmental flow requirements of water-dependent features of the Namoi River require further investigation to determine more specific environmental watering orders.

Table 4: Namoi asset environmental watering objectives for ecological objectives

Notes:
1. See broad-scale objectives in Table 3. Ecological objectives may change as water is accrued for each climate scenario as per Table 6.
2. Appendix 3 provides the background for the development of these objectives. Operational detail is provided in Table 11.

Asset	WMA	Climate sequence scenario	Ecological objectives[1]	Asset environmental watering objective[2]
Split Rock Dam to Keepit Dam	River channel	Extreme dry	Maintain in-stream refuges and aquatic habitat for native fish species and platypus in pools. Maintain water quality within channels and pools. Prevent fish stranding and allow biota to complete flow-driven critical life cycle processes such as spawning, seed setting and dormant stages.	Contributing to baseflow to maintain in-stream refuges and aquatic habitat.
		Dry	Maintain habitat for native fish species and platypus in pools and connectivity through wetting of low-level point bars and riparian zone. Reset in-stream biofilms and maintain water quality within channels and pools. Promote diversity outcomes by flooding low-level benches.	Contributing to baseflow to maintain in-stream refuges and aquatic habitat. Bulk water transfer to provide connectivity and freshes. Inundate low-level benches.
		Median	Inundate low commence-to-flow riparian wetlands and mid-level benches; protect platypus breeding habitat. Reset in-stream biofilms and maintain water quality within channels and pools. Provide triggers for fish-spawning opportunities.	Provide pulse flows to inundate medium-level benches and riparian assets.
		Wet	Inundate higher commence-to-flow riparian wetlands and mid-level benches; protect platypus breeding habitat. Reset in-stream biofilms and maintain water quality within channels and pools. Increase connectivity between floodplain and channels to promote primary productivity and support water-dependent species.	Provide pulse flows to inundate high-level benches, riparian assets and connectivity with adjacent floodplain through pulsed flows.

Asset	WMA	Climate sequence scenario	Ecological objectives[1]	Asset environmental watering objective[2]
Keepit Dam to Carroll	River channel	Extreme dry	Maintain in-stream refuges and aquatic habitat for native fish species. Maintain water quality within channels and pools. Prevent fish stranding and allow biota to complete flow-driven critical life cycle processes such as spawning, seed setting and dormant stages.	Contribute to baseflow to maintain in-stream refuges and aquatic habitat.
		Dry	Maintain in-stream refuges and aquatic habitat, maintain in-channel geomorphic structure and organic matter inputs. Maintain water quality within channels and pools. Promote diversity outcomes by flooding low-level benches.	Contribute to baseflow to maintain in-stream refuges and aquatic habitat. Provide pulsed flows for wetting and connectivity with low-level benches and point bars.
		Median	Support riparian vegetation and maintain in-channel geomorphic structure and organic matter inputs. Maintain water quality within channels and pools. Provide triggers for fish-spawning opportunities.	Provide pulse flows for wetting and connectivity with medium-level benches, point bars and riparian zone.
		Wet	Support riparian vegetation and floodplain river red gum woodland. Maintain in-channel geomorphic structure and organic matter inputs. Maintain water quality within channels and pools. Increase connectivity between floodplain and channels to promote primary productivity.	Provide pulse flows for wetting and connectivity with higher level benches, point bars and riparian zone.
Carroll to Boggabri	River channel	Extreme dry	Maintain in-stream refuges and aquatic habitat. Maintain water quality within channels and pools. Prevent fish stranding and allow biota to complete flow-driven critical life cycle processes such as spawning, seed setting and dormant stages.	Contribute to baseflow to maintain in-stream refuges and aquatic habitat.
		Dry	Maintain in-stream refuges and aquatic habitat. Maintain in-channel geomorphic structure and organic matter inputs. Maintain water quality within channels and pools. Promote diversity outcomes by flooding low-level benches.	Contribute to baseflow to maintain in-stream refuges and aquatic habitat. Provide pulsed flows for wetting and connectivity with low-level benches, point bars and riparian zone.
		Median	Support riparian vegetation and maintain in-channel geomorphic structure and organic matter inputs. Maintain water quality within channels and pools. Provide triggers for fish-spawning opportunities.	Provide pulse flows for wetting and connectivity with medium-level benches, point bars and riparian zone.
		Wet	Support riparian vegetation and floodplain red gum woodland. Maintain in-channel geomorphic structure and organic matter inputs. Maintain water quality within channels and pools. Increase connectivity between floodplain and channels to promote primary productivity.	Provide pulse flows for wetting and connectivity with higher level benches, point bars and riparian zone.

Asset	WMA	Climate sequence scenario	Ecological objectives[1]	Asset environmental watering objective[2]
Boggabri to Wee Waa	Narrabri Creek Channel	Extreme dry	Maintain in-stream refuges and aquatic habitat. Maintain water quality within channels and pools. Prevent fish stranding and allow biota to complete flow-driven critical life cycle processes such as spawning, seed setting and dormant stages.	Contribute to baseflow to maintain in-stream refuges and aquatic habitat.
		Dry	Maintain in-stream refuges and aquatic habitat, maintain in-channel geomorphic structure and organic matter inputs. Maintain water quality within channels and pools. Promote diversity outcomes by flooding low-level benches.	Contribute to baseflow to maintain in-stream habitat. Wet low-level benches and point bars through pulsed flows.
		Median	Support riparian vegetation and maintain in-channel geomorphic structure and organic matter inputs. Maintain water quality within channels and pools. Provide triggers for fish-spawning opportunities.	Provide pulse flows for wetting and connectivity with medium-level benches, point bars and riparian zone.
		Wet	Support riparian vegetation and floodplain river red gum woodland. Maintain in-channel geomorphic structure and organic matter inputs. Maintain water quality within channels and pools. Increase connectivity between floodplain and channels to promote primary productivity.	Provide pulse flows for wetting and connectivity with higher level benches, point bars and riparian zone.
	Namoi River upstream Mollee Weir	Extreme dry	Maintain aquatic habitat. Maintain water quality within channels and pools. Prevent fish stranding and allow biota to complete flow-driven critical life cycle processes such as spawning, seed setting and dormant stages.	Contribute to baseflow to maintain in-stream aquatic habitat.
		Dry	Provide in-stream aquatic habitat. Maintain in-channel geomorphic structure and organic matter inputs. Maintain water quality within channels and pools. Promote diversity outcomes by flooding low-level benches.	Contribute to baseflow to maintain in-stream aquatic habitat. Provide pulse flows for wetting and connectivity with low-level benches and point bars.
		Median	As above. Provide triggers for fish breeding opportunities.	As above
		Wet	Support riparian vegetation and floodplain river red gum woodland. Maintain in-channel geomorphic structure and organic matter inputs. Maintain water quality within channels and pools. Increase connectivity between floodplain and channels to promote primary productivity.	Provide pulse flows for wetting and connectivity with higher level benches, point bars and riparian zone.

Asset	WMA	Climate sequence scenario	Ecological objectives[1]	Asset environmental watering objective[2]
Boggabri to Wee Waa	Anabranches from Mollee Weir to Gunidgera Weir	Extreme dry	Support natural drying cycle and habitat for native fish. Maintain in-channel geomorphic structure and organic matter inputs.	Contribute to baseflow to maintain in-stream aquatic habitat.
		Dry	Provide in-stream aquatic habitat, maintain in-channel geomorphic structure and organic matter inputs. Maintain native water plants for improved water quality and wetland habitat outcomes. Promote diversity outcomes through wetting associated riverine areas.	Contribute to baseflow to maintain in-stream habitat. Support wetting and connectivity with low-level benches and point bars through pulsed flows.
		Median	Support riparian vegetation and maintain in-channel geomorphic structure and organic matter inputs. Provide triggers for fish-spawning opportunities. Provide nesting and foraging habitat for waterbirds such as ibis, freckled duck, blue-billed duck, egrets and herons.	Provide pulsed flows for wetting and connectivity with medium-level benches, point bars and riparian zone.
		Wet	Support riparian vegetation and floodplain river red gum woodland. Maintain in-channel geomorphic structure and organic matter inputs. Increase connectivity between floodplain and channels to promote primary productivity and support floodplain vegetation.	Provide pulse flows for wetting and connectivity with higher level benches, point bars and riparian zone.
	Barbers Lagoon	Extreme dry	Provide natural drying cycle.	
		Dry	As above.	
		Median	Support riparian vegetation and maintain refuge pools. Provide triggers for fish-spawning opportunities. Provide nesting and foraging habitat for waterbirds such as ibis, freckled duck, blue-billed duck, egrets, herons.	Provide pulsed flows for wetting and connectivity with low-level benches, point bars and riparian zone.
		Wet	Support riparian vegetation and floodplain river red gum woodland. Increase connectivity between floodplain and channels to promote primary productivity. Provide adequate flooding regime to support vegetation associated with channels and floodplains. Maintain open water areas by providing adequate flooding flows. Provide nesting and foraging habitat for waterbirds such as freckled duck, blue-billed duck, egrets, herons.	Provide wetting of riparian zone and floodplain red gums through higher flows.

Asset	WMA	Climate sequence scenario	Ecological objectives[1]	Asset environmental watering objective[2]
Wee Waa to Walgett	River channel	Extreme dry	Maintain in-stream aquatic habitat. Maintain water quality within channels and pools. Prevent fish stranding and allow biota to complete flow-driven critical life cycle processes such as spawning, seed setting and dormant stages.	Contribute to baseflow to maintain in-stream aquatic habitat.
		Dry	Contribute to ecological requirements through piggybacking flows to the Barwon-Darling. Maintain in-stream aquatic habitat, maintain in-channel geomorphic structure and organic matter inputs. Maintain water quality within channels and pools. Promote diversity outcomes by flooding low-level benches.	Contribute to baseflow to maintain in-stream aquatic habitat. Provide pulsed flows for wetting and connectivity with low-level benches and point bars. Increase end-of-system flow to Barwon-Darling.
		Median	Contribute to ecological requirements through piggybacking flows to the Barwon-Darling. Support riparian vegetation and maintain in-channel geomorphic structure and organic matter inputs. Maintain water quality within channels and pools. Provide triggers for fish spawning opportunities.	Provide pulsed flows for wetting and connectivity with medium-level benches, point bars and riparian zone. Increase end-of-system flow to Barwon-Darling.
		Wet	Contribute to ecological requirements through piggybacking flows to the Barwon-Darling. Support riparian vegetation and floodplain river red gum woodland. Maintain in-channel geomorphic structure and organic matter inputs. Maintain water quality within channels and pools. Increase connectivity between floodplain and channels to promote primary productivity.	Provide pulsed flows for wetting and connectivity with higher level benches, point bars and riparian zone. Increase floodplain connectivity and reach commence-to-flow targets for warrambools. Increase end-of-system flow to Barwon-Darling.
	Duncans Warrambool	Extreme dry	Maintain in-stream aquatic habitat. Maintain water quality within channels and pools. Prevent fish stranding and allow biota to complete flow-driven critical life cycle processes such as spawning, seed setting and dormant stages.	Contribute to baseflow to maintain in-stream aquatic habitat.
		Dry	Provide in-stream aquatic habitat, maintain in-channel geomorphic structure and organic matter inputs. Maintaining native water plants for improved water quality and wetland habitat outcomes. Promote diversity outcomes through wetting associated riverine areas.	Contribute to baseflow to maintain in-stream aquatic habitat. Provide pulsed flows for wetting and connectivity with low-level benches and point bars.
		Median	Support riparian vegetation and maintain in-channel geomorphic structure and organic matter inputs. Provide triggers for fish-spawning opportunities. Provide nesting and foraging habitat for waterbirds such as ibis, freckled duck, blue-billed duck, egrets, herons.	Provide pulsed flows for wetting and connectivity with medium-level benches, point bars and riparian zone.
		Wet	Support riparian vegetation and maintain in-channel geomorphic structure and organic matter inputs. Increase connectivity between floodplain and channels to promote productivity. Provide adequate flooding regime to support vegetation associated with channels and floodplains. Maintain open water areas by providing adequate higher flows to lagoons. Provide nesting and foraging habitat for waterbirds such as freckled duck, blue-billed duck, egrets, herons.	Provide pulsed flows for wetting and connectivity with higher level benches, point bars and riparian zone.

Asset	WMA	Climate sequence scenario	Ecological objectives[1]	Asset environmental watering objective[2]
Pian Creek	Channel	Extreme dry	Baseflow to maintain in-stream aquatic habitat. Maintain water quality within channels and pools. Prevent fish stranding and allow biota to complete flow driven critical life cycle processes such as spawning, seed setting and dormant stages.	Contribute to baseflow to maintain in-stream aquatic habitat.
		Dry	Baseflow to maintain in-stream aquatic habitat. Provide wetting and connectivity with low level benches. Maintain water quality within channels and pools. Promote diversity outcomes by flooding low level benches.	Contribute to baseflow to maintain in-stream aquatic habitat. Provide pulsed flows for wetting and connectivity with low-level benches and point bars
		Median	Provide wetting and connectivity with medium level benches, point bars and riparian zone. Maintain water quality within channels and pools. Provide triggers for fish spawning opportunities.	Provide pulsed flows for wetting and connectivity with medium-level benches, point bars and riparian zone
		Wet	Provide wetting and connectivity with higher level benches, point bars and riparian zone. Maintain water quality within channels and pools. Increase connectivity between floodplain and channels to promote primary productivity.	Provide pulsed flows for wetting and connectivity with higher level benches, point bars and riparian zone
Peel River		Extreme dry	Baseflow to maintain in-stream refuges and aquatic habitat. Maintain water quality within channels and pools.Prevent fish stranding and allow biota to complete flow-driven critical life cycle processes such as spawning, seed setting and dormant stages.	Contribute to baseflow to maintain in-stream refuges and aquatic habitat.
		Dry	Baseflow to maintain in-stream aquatic habitat. Provide wetting and connectivity with low-level benches. Maintain water quality within channels and pools. Promote diversity outcomes by flooding low level benches.	Contribute to baseflow to maintain in-stream aquatic habitat. Provide pulsed flows for wetting and connectivity with low-level benches and point bars. Increase flow variability.
		Median	Provide wetting and connectivity with medium-level benches, point bars and riparian zone. Maintain water quality within channels and pools. Provide triggers for fish spawning opportunities.	Provide wetting and connectivity with medium-level benches, point bars and riparian zone. Provide pulsed flows for wetting and connectivity with low-level benches and point bars. Increase flow variability.
		Wet	Provide wetting and connectivity with higher level benches, point bars and riparian zone. Maintain water quality within channels and pools. Increase connectivity between floodplain and channels to promote primary productivity.	Provide wetting and connectivity with higher level benches, point bars and riparian zone. Provide pulsed flows for wetting and connectivity with low-level benches and point bars. Increase flow variability.

3.3 Water availability under each climate scenario

The allocation systems for the different types of water access licenses in the Namoi catchment are presented in Table 5.

Table 5: Namoi catchment allocation systems

Upper Namoi River	Domestic and stock	Annual allocation	Normally allocated 1 ML/unit share each year.
	Local water utility	Annual allocation	Normally allocated 1 ML/unit share each year.
	Regulated river (high security)	Annual allocation	Normally allocated 1 ML/unit share each year.
	Regulated river (general security)	Annual allocation with carryover	Carry over of up to 0.5 ML/unit share but limit of 1 ML/unit share in account at any time. Allocations depend on level in Split Rock Dam, which also services entitlements in the lower Namoi.
	Supplementary water	Annual allocation	1 ML/unit share.
Lower Namoi River	Domestic and stock	Annual allocation	Normally allocated 1 ML/unit share each year.
	Local water utility	Annual allocation	Normally allocated 1 ML/unit share each year.
	Regulated river (high security)	Annual allocation	Normally allocated 1 ML/unit share each year.
	Regulated river (general security)	Continuous accounting	Maximum in account at any time: 2 ML/unit share. Maximum allowable account volume for all regulated river entitlements equals approximately 80% of maximum allocable storage.
	Supplementary water	Annual allocation	1 ML/unit share.

An indication of the volumes that would be available to general and high-security access licences in the Namoi water accounts under each climate scenario is provided in Table 6. The volumes represent the water available in an account at a particular time of year, and do not represent the water likely to be allocated over the course of a water year. As a consequence the volumes decrease from October to April reflecting both the usage from the account and the inflows to the accounts over this time period. At the time of developing this document Commonwealth environmental water was the only licensed environmental water in the Namoi catchment (see Section 8.1). For this reason modelling for this report has been based solely on Commonwealth environmental water holdings.

This information has been derived using the NSW Office of Water's Namoi IQQM model, which is based on a 'typical' irrigation demand pattern. As an environmental user's pattern of demand may be quite different to this, the account volumes may vary from those presented in Table 6. To better reflect the allocations available to an environmental water user would require a reconfiguration of some demand patterns in the Namoi hydrology model. In addition, Commonwealth environmental water holdings are subject to change – current figures can be found at: http://www.environment.gov.au/ewater.

Table 6: Likely allocation and volume available to the environment from Commonwealth environmental water entitlements

			October allocation				April allocation			
Holder	Licence volume	Entitlement category	Very dry	Dry	Median	Wet	Very dry	Dry	Median	Wet
General security access licence allocation (%)			2	55	98	141	0	29	76	124
High security access licence allocation (%)			100	100	100	100	100	100	100	100
Commonwealth environmental water (ML)	6,203	General	148	3,430	6,072	8,734	0	1,786	4,689	7,717

Analysis of IQQM data indicates that under an extremely dry or dry climate the watering of Namoi assets using stored environmental water has limited feasibility with only 2–55 per cent of general-security entitlement volume available in the water account in October and 0–29 per cent available in April (Table 6). Based on Commonwealth environmental water entitlements (as at September 2011), there would be a maximum of 1,786 megalitres in the general-security account under a dry-climate sequence in April (Table 6). On its own, this volume would be sufficient to water a limited number of in-channel assets, with more watering options dependent on piggybacking opportunities.

Under a median or wet climate the watering of more Namoi assets would be feasible with the available general-security account volumes (Table 6), and particularly with piggybacking opportunities. Forecasts indicate that between 98–141 per cent of general-security entitlement would be available in the account under median-to-wet conditions in October and 76–124 per cent in April (Table 6). Based on Commonwealth environmental water entitlements (as at September 2011) between 4,689 megalitres and 8,734 megalitres of general-security water would potentially be available for use.

The probability of unregulated stream flows in the Namoi River at Wee Waa are presented under different climate scenarios in Appendix 4.

There are currently no Commonwealth environmental water-licenced entitlements for the Peel River. However, as described in section 1.5.2, current environmental water rules require up to a 1,600-megalitre stimulus flow to be provided when the Chaffey storage exceeds 50,000 megalitres at the start of the water year. The Water Sharing Plan for the Peel River provides for the creation of a 5,000-megalitre environmental contingency allowance when the capacity of Chaffey Dam is enlarged to 100,000 megalitres (currently 62,000 megalitres).

PART 2:
Water use strategy

4. Environmental water requirements

4.1 Watering requirements

Asset environmental watering objectives were presented in the previous section. The associated watering requirements and delivery regimes to meet these objectives are presented below (Table 7). Watering requirements for wetland-dependent vegetation and ecological components have been documented in a number of reports including Roberts and Marston (2000), Davis et al. (2001) and Rogers and Ralph (2010). Fish-specific requirements have been extracted from Lintermans (2007) and NSW Fisheries Guidelines (2001). While this list is not exhaustive it provides detailed information on a number of important features associated with Namoi assets.

These watering requirements have been used to determine appropriate water-delivery regimes for Namoi assets/WMAs (section 5 and Table 10).

Table 7: Watering requirements for water-dependent species of the Namoi River

Water dependent component	Ideal frequency	Ideal duration	Max duration	Ideal timing	Max timing	Ideal depth	Max depth	Ideal dry spell	Max dry spell
Plant survival and maintenance									
River red gum	1–3 years	2–8 months	24 months	Winter- spring	Winter-early summer	N/A	N/A	5–15 months	36–48 months
Black box	1 in 2–5 years	2–4 months	5 months	Any	Any	N/A	N/A	Variable	Unknown
Lignum	3–10 years	1–6 months	12 months	Spring-early summer	Not critical	0–60 cm	Generally <1m	1- 10 years	Unknown
Common reed	1–2 years	~6 months	12 months or permanent	Spring	Any	20- 50 cm	2 m	Few months	12 months
Waterbird breeding									
Great and intermediate egret	Not known	12 months 3–4 months breeding	N/A	Nov-May	Sept-May	Deep- slow fall	N/A	Not listed	Not listed
Little egret	Not known	6 months 3–4 months breeding	N/A	Oct- March	Not listed	Deep- mod fall	N/A	Not listed	Not listed
Straw-necked ibis	Not known	9–12 months 3 months breeding	N/A	Sept- Feb	Any time	0.5–1 m slow fall	N/A	Not listed	Not listed
Glossy ibis	Not known	2 months breeding	N/A	Oct- Feb	Not listed	Deep- slow fall	N/A	Not listed	Not listed
Grey teal	Not known	4–5 months 3–4 breeding	N/A	June-Feb	Any time	Unknown- mod fall	N/A	Not listed	Not listed

Water dependent component	Ideal frequency	Ideal duration	Max duration	Ideal timing	Max timing	Ideal depth	Max depth	Ideal dry spell	Max dry spell
Freckled duck	Not known	5 months 3 months breeding	N/A	June- Dec	Anytime	Unknown mod-slow fall	N/A	Not listed	Not listed
Brolga	Not known	3–4 months		July-Nov	May-March	0.24–0.72 m	N/A	Not listed	Not listed
Native fish[6]									
Purple spotted gudgeon	Annually	Not listed	Not listed	Spring when temp. ≥20°	Not listed	To achieve bed scouring; Wetland inundation	Not listed	Nil for in-channel	Nil for in-channel
Murray cod	Min. 1 in every 5 to 10 years	Min. 4 weeks	Not listed	Spring when temp. ≥16°	Not listed	Fluctuations to aid spawning, dispersal and food production	Commence-to-flow to achieve floodplain inundation	Nil for in-channel	Nil for in-channel
Golden perch	Min. 1 in every 3 to 5 years	Min. 3 weeks	Not listed	Spring & summer when temp. ≥23°	Not listed	Fluctuations to aid spawning, dispersal and food production	Commence-to-flow to achieve floodplain inundation	Nil for in-channel	Nil for in-channel
Silver perch	1 in 5–10 years	Min. 4 weeks	Not listed	Spring when temp. ≥23°	Not listed	20–100mm fluctuations	Not listed	Nil for in-channel	Nil for in-channel
Freshwater catfish	Annually	Not listed	Not listed	Spring when temp. ≥24°	Not listed	Ensure sufficient to refresh wetlands.	Not listed	Nil for in-channel	Nil for in-channel
Olive perchlet	Not listed	Not listed	Not listed	Spring when temp >25°	Not listed	Inundate backwaters; 1m with no flow	Not listed	Nil for in-channel	Nil for in-channel
Unspecked hardyhead	Not listed	Not listed	Not listed	Oct-Feb	Not listed	Not listed	Not listed	Not listed	Not listed

[6] Ideal Frequency for native fish refers to floodplain or anabranch inundation; NB native fish require regular seasonal instream freshes for population maintenance.

Water dependent component	Ideal frequency	Ideal duration	Max duration	Ideal timing	Max timing	Ideal depth	Max depth	Ideal dry spell	Max dry spell
Northern river blackfish	Not listed	Not listed	Not listed	Oct- Jan	Not listed	Not listed	Not listed	Not listed	Not listed
River snail	Frequent fluctuations	Not listed	Not listed	Not listed	Not listed	Wetted and dried perimeter cycles	Not listed	Not listed	Not listed
Frogs			Tadpoles						
Eastern froglet	<3 months-permanent	Not listed	2–4 months	Summer-Autumn	Not listed	Not listed	Not listed	Not listed	Not listed
Perons tree frog	<3 months-permanent	Not listed	3–4 months	Summer	Not listed	Not listed	Not listed	Not listed	Not listed
Southern bell frog	3 months-permanent	Not listed	3–5 months	Summer	Not listed	Not listed	Not listed	Not listed	Not listed

Source: Modified from Rogers and Ralph 2010; Lintermans 2007; NSW Fisheries 2001.
Note: Rogers and Ralph (2010) also provides additional information on other outcomes such as reproduction and regeneration requirements and a functional classification for floodplain plants.

5. Operating regimes and environmental water delivery strategies

In order to achieve the environmental watering objectives for an asset and WMA, flows need to be delivered at an appropriate volume, duration and time. For successful water delivery there are many factors that need to be considered in terms of determining the requirements of the 'environmental water order'. The combination of these factors forms the operational delivery regime. The main considerations and the resulting likely water orders for assets on the Namoi and Peel rivers are provided below.

State Water Corporation is the river operator within the Namoi catchment and has responsibility for addressing the operational considerations and determining the dam release requirements to meet environmental water orders. Section 5.2 and Table 10 provide possible water orders for each asset/WMA.

The modest volume of environmental water currently held in the Namoi catchment limits how this water can be effectively used on its own to meet the water orders provided in Table 10. Consequently, there is likely to be high reliance on piggybacking delivery arrangements to meet the proposed water objectives.

5.1 Delivery considerations

5.1.1 Travel time for delivery of environmental water

The length of time it takes for environmental water to reach a targeted asset from a water storage is an important consideration when planning environmental watering events. The following approximate travel times are relevant but can vary depending on the antecedent conditions of the channel. The longer delivery times are for when the river channel is dry prior to the release:

- Chaffey–Namoi: 3 to 4 days
- Split Rock–Keepit: 4 to 5 days
- Keepit Dam–Boggabri: 3 to 6 days
- Boggabri–Narrabri: 2 to 4 days
- Narrabri–Wee Waa: 2 to 4 days
- Wee Waa–Walgett: 15 to 30 days
- Wee Waa–end Pian Creek regulated (Dundee weir): 10 to 20 days.

5.1.2 Storage release capacities

The following information on release capacities applies to each storage at maximum storage levels (DLWC 2002). Any order for environmental water needs to consider limitations that arise from storage release capacity, which will decrease as the storage level drops. Other water orders may also affect possible valve and channel capacity sharing. Storage release capacities are:

- Split Rock Dam has a maximum release capacity of 6,000 ML/d, however, due to the following environmental reasons the discharge has been limited to a maximum of 4,500 ML/d:
  - possible drowning of platypus colonies
  - damage to the river channel
  - native fish kills due to large releases (resulting from trapping in trash rack due to high flow velocities)
  - cut-off access to some landholders
- Keepit Dam maximum fixed outlet release capacity is 4,000 ML/d.
- Keepit Dam also has flood mitigation gates which become operational at storage levels above 25 per cent (spillway crest wall height 318.595 metres). The following releases can be achieved via these gates, however, it should be noted that the operation of these gates at lower discharges is more complex and there will be less precision with the volumes than via the dam outlet valves:
  - 25 per cent (storage height 318.65 metres)—minimal release possible (State Water has advised that the release rate from Keepit Dam at this storage height is very small and difficult to quantify (S Samarawickrama (State Water) 2011, pers. comm.)
  - 30 per cent (storage height 319.86 metres)—maximum release 20 GL/d
  - 40 per cent (storage height 321.88 metres)—maximum release 90 GL/d
- Chaffey Dam maximum release capacity is 1,100 ML/d.

The Water Sharing Plan takes into account the total reserves of Split Rock and Keepit Dams, and when reserves in Keepit Dam cannot satisfy the water usage requirements for irrigators downstream of the dam it may be necessary to transfer reserves from Split Rock. The volumes of water required for bulk transfers can vary depending on the conditions in both Split Rock and Keepit dams and the predicted demands.

A trial release of approximately 26,350 megalitres was undertaken over 19 days in September 2000 (see Table 8) to assess the potential impact of proposed bulk water transfers from Split Rock Dam on the hydrology and environment of the Manilla River. The trial release was also designed to develop operational criteria to protect against adverse environmental impacts downstream (Foster 2001).

This trial release found that there were no detrimental effects on the in-stream environment of the Manilla River. Visual assessment of the flows during the release indicated that no inconvenience or damage was incurred to irrigation operations or infrastructure during the period of the trial (Foster 2001). As the assessment was only undertaken over one release, no conclusions could be drawn on the longer term effects of the flow regime which was designed to mimic a natural flow event (Foster 2001). Rules associated with these transfers are discussed in section 8.4.

Table 8: Release rate for trial bulk water transfer from Split Rock to Keepit Dam

Day	Volume of release from Split Rock Dam (ML/d)
1	150
2	200
3	300
4	600
5	2,000
6	3,500
7	4,500
8	4,100
9	2,100
10	1,200
11	2,300
12	1,900
13	1,200
14	800
15	600
16	500
17	300
18	100
19	Repeat cycle as necessary

Source: Foster 2001.

5.1.3 Channel capacities

Generally, the Namoi channel is capable of containing the maximum release of 4,000 ML/d from Keepit Dam, while the channel capacity between Split Rock and Keepit Dam is estimated at 4,500 ML/d. Channel capacity for the Peel River has not been defined (S Samarawickrama (State Water) 2011, pers. comm.).

The parts of the system which have channel capacity limitations for regulated water delivery purposes are:

- Pian Creek, with a maximum channel capacity estimated at 2,000 ML/d
- Gunidgera off-take, which regulates flows into Pian Creek, has a capacity of 1,250 ML/d.

Moderate-to-major flooding at Gunnedah occurs at volumes above 48,500 ML/d. Similar volumes result in flooding at Boggabri and Narrabri (S Samarawickrama (State Water) 2011, pers. comm.).

5.1.4 Availability of conveyance water

Conveyance water is provided to 'run the river' and provide for natural water losses which occur along the river/creek channels due to "water evaporation and seepage from surface water sources and man-made water transportation features, such as irrigation channels" (NWC 2011). On most parts of regulated rivers, water orders for extractive or environmental use (orders) are provided 'on top of' the conveyance water. In NSW the volumetric requirements to provide for conveyance water are shared among all users and is accounted for when the annual and progressive water resource assessment is undertaken by the NSW Office of Water in conjunction with State Water.

There is no constant conveyance baseflow provided on the Namoi.

5.1.5 Piggybacking opportunities

The Namoi River maintains an average daily flow of 1,922 ML/d at Gunnedah, while downstream flows decrease to around 1,500 ML/d due to the significant irrigation extractions and diversions into effluent channels (Green et al. 2011). The long-term average annual flow in the Namoi River at Gunnedah is 696,000 megalitres. At the time of preparing this report, the most recent flooding occurred in August and December 2010 when peaks of 30,000 megalitres and 54,000 megalitres per day respectively were recorded at Gunnedah (Green et al. 2011). These volumes resulted in minor-to-moderate flooding in the Gunnedah area. The bulk of irrigation flows tend to be delivered in summer months.

The existence of conveyance water in parts of the Namoi catchment provides for piggybacking opportunities to assist the efficiency of delivery of environmental water orders. Other water in the river also provides opportunities for piggybacking including stock and domestic replenishments, other (irrigation, bulk water orders from Split Rock) water orders and unregulated flow events.

In this context the supplementary water rules for extraction in the Water Sharing Plan are repeated here, as they provide different opportunities to use held environmental water allocation in conjunction with supplementary events. This would improve operational flexibility and ensure the greatest environmental benefit from environmental releases through improved management of supplementary flows:

- During a supplementary water event, extraction may not exceed 10 per cent of the supplementary event volume for events occurring between 1 July and 31 October, and 50 per cent of the supplementary event volume for events between 1 November and 30 June.

5.1.6 Water delivery costs

The water charges which apply to water entitlements and water use in the Namoi catchment are listed in Table 9.

Table 9: Water charges for Namoi River water entitlements and use

Charges from 1 July 2011 to 30 June 2012*	High Security	General security
State Water		
Entitlement charge ($/ML)	$13.56	$9.00
Usage charge ($/ML)	$19.55	$19.55
Resource Management (NSW Office of Water)		
Entitlement charge ($/ML)	$1.84	$1.84
Usage charge ($/ML)	$1.26	$1.26

*Charges rise progressively, indexed to the consumer price index, until June 2014 when the next IPART determination is made.

Costs incurred for infrastructure maintenance by State Water are covered by these charges.

At this time there is no pumping of water to assets on the Namoi River and therefore no costs associated with this.

5.2 Water orders for Namoi environmental assets

The information in Table 10 provides guidance for the water order which would be required to meet the water requirements for each asset/WMA presented in Table 4. The water orders in Table 10 consider the essential parameters that would be provided to State Water as per their water order application form (see Appendix 5). The extraction details for bulk orders required under the order form are:

- start date
- number of days pumping (or duration of the flow for environmental assets)
- volume per day in megalitres.

A form for the use of multiple licenses for the water order can be obtained from State Water at: http://www.statewater.com.au/_Documents/Customer%20Service%20library/multiple%20licence%20order%20form.pdf.

The delivery and accounting locations relating to water orders are subject to meeting conditions detailed under Section 8E of the *Water Management Act 2000* (NSW) (see section 6.2).

The determination of the delivery requirements for the water-dependent assets of the Namoi River will be subject to the conditions which exist at the time of watering in addition to delivery constraints, some of which are outlined above (see section 5.1). The actual water-delivery specifications will be determined by State Water.

Where available, pre-existing information on the riverine assets of the Namoi River has been used to develop the water orders outlined below. However, for the in-channel assets there is very little information available to develop the water orders and consequently the current minimum conveyance flows have been used as the basis for the development of water orders. This assumes that other water releases, such as minimum-flow deliveries and replenishment flows under very dry to dry conditions and irrigation water supply under median and wet conditions, are generally sufficient to meet baseflow requirements.

Water orders for higher elevation floodplain assets have not been included in this document as delivery to these sites would require large volumes beyond that currently held as environmental water. In addition, delivery to many of these assets is not feasible given current delivery constraints.

Table 10: Water orders to meet environmental watering objectives for Namoi assets and water management areas

Notes:

1. The water orders presented in Table 10 are approximations of the delivery regime that would be required to meet the ecological objectives presented in Table 4. Water orders will be developed further with river operators, to account for operating rules and delivery constraints.

2. Because the durations of flows to meet the ecological objectives are not known, the water orders provided are for a range of requirements from 1 to 5 days. Environmental water order does not include conveyance or piggybacking water requirements, although some indication of these requirements are given where known. The baseflows and water for consumptive use (e.g. replenishment flows) are not to be substituted by held environmental water. In instances when these flows are not provided, additional water may need to be provided from held environmental water to meet the watering objectives. In some systems this may not be feasible given the volume that would be required. Regardless of this, the water order parameters for the baseflows or water for consumptive use are provided. Due to current delivery constraints (outlined above), achieving target flow rates will be dependent on conditions at the time of watering, including tributary inflows.

Asset	WMA	Climate scenario (from Table 5)	Asset environmental watering objective[1]	Environmental water order[2]
Split Rock Dam to Keepit Dam	River channel	Extreme dry	Contribute to baseflow to maintain in-stream refuges and aquatic habitat. Maintain water quality. Reset in-stream biofilms. Prevent fish stranding and allow biota to complete critical life cycle.	Current minimum releases from Split Rock are about 5 ML/d. It is not known if these releases meet the watering objective.
		Dry	Contribute to baseflow to maintain in-stream refuges, aquatic habitat and water quality; reset in-stream biofilms; bulk water transfer to provide connectivity and freshes. Inundate low-level benches.	The volumes of water required for bulk transfers can vary depending on the conditions in both Split Rock and Keepit storages and the predicted demands (see section 5.1.2). Transfers are made to mimic natural flows and involve gradual increases and falls in the hydrograph with a maximum daily release of 4,500 ML/d from Split Rock Dam.
		Median	Contribute to baseflow to maintain in-stream refuges, aquatic habitat and water quality; reset in-stream biofilms.	As above.
		Wet	Contribute to baseflow to maintain in-stream refuges, aquatic habitat and water quality; reset in-stream biofilms.	As above.
Keepit Dam to Carroll	River channel	Extreme dry	No water delivered under extremely dry conditions.	None. Water requirements are likely to be met by other regulated releases.
		Dry	Contribute to baseflow to maintain in-stream refuges, aquatic habitat and water quality. Provide wetting and connectivity with low-level benches and point bars.	Contribute to baseflow of 72 ML/d at Boggabri gauge. A total volume of 4,000–20,000 ML to maintain flows at 4,000 ML/d for 1 to 5 days at Gunnedah Gauge would achieve this objective. Commence-to-flow for benches and point bars (2,000–4,000 ML/d) could be delivered via the use of the flood gates when the storage is above 23% and with piggybacking on unregulated flows. Flows of >4,600 ML/d are required at Boggabri to inundate low commence-to-flow wetlands.

Asset	WMA	Climate scenario (from Table 5)	Asset environmental watering objective[1]	Environmental water order[2]
Keepit Dam to Carroll	River channel	Median	Provide wetting and connectivity with higher level benches, point bars and riparian zone. Maintain water quality.	Contribute a total volume of 7,000–35,000 ML to maintain flows at 7,000 ML/d for 1 to 5 days at Gunnedah gauge (commence-to-flow for higher level benches 4,000–7,000 ML/d)—see above. Flows of >4,600 ML/d are required at Boggabri to inundate low commence-to-flow wetlands.
		Wet	Provide wetting and connectivity with higher level benches, point bars and riparian zone. Maintain water quality.	As above.
Carroll to Boggabri	River Channel	Extreme dry	No water delivered under extremely dry conditions.	None. Water requirements are likely to be met by other regulated releases.
		Dry	Contribute to baseflow to maintain in-stream refuges, aquatic habitat and water quality. Provide wetting and connectivity with low-level benches.	Baseflow is likely to be provided by other regulated releases. Maintain flows of 72 ML/d at Boggabri to provide low-flow season for native fish. Flows of 215 ML/d at Boggabri would provide high-flow season for native fish. Contribute a total volume of 5,000–25,000 ML to maintain flows at 5,000 ML/d for 1 to 5 days at Gunnedah gauge (commence-to-flow for low level benches is 5,000–8,000 ML/d). Flows of >4,600 ML/d are required at Boggabri to inundate low commence-to-flow wetlands.
		Median	Provide wetting and connectivity with medium-level benches, point bars and riparian zone. Maintain water quality.	Contribute between 8,000–40,000 ML to maintain flows of 8,000 ML/d for 1 to 5 days at Gunnedah gauge—(commence-to-flow 5,000–8,000 ML/d). Flows of 1,400–2,870 ML/d at Boggabri between Sep–Dec for a minimum of 7 days are required to support native fish spawning/recruitment.
		Wet	Provide wetting and connectivity with higher level benches, point bars and riparian zone. Maintain water quality.	Contribute between 15,000–75,000 ML to maintain flows of 15,000 ML/d for 1 to 5 days at Gunnedah gauge—(commence-to-flow for higher benches and riparian zone is15,000 ML/d). Flows of 1,400–2,870 ML/d at Boggabri between Sep–Dec for minimum of 7 days are required to support native fish spawning/recruitment.

Asset	WMA	Climate scenario (from Table 5)	Asset environmental watering objective[1]	Environmental water order[2]
Boggabri to Wee Waa	Narrabri Creek Channel	Extreme dry	No water delivered under extremely dry conditions.	None. Water requirements are likely to be met by other regulated releases.
		Dry	Contribute to baseflow to maintain in-stream refuges, aquatic habitat and water quality. Provide wetting and connectivity with low-level benches.	Baseflow is likely to be provided for by other regulated releases. Flows of 72 ML/d at Boggabri are required to provide low-flow season for fishery purposes. Flows of 215 ML/d are required at Boggabri to provide high-flow season for native fish. Commence-to-flow of in-channel, low-elevation floodplain to achieve this not known.
		Median	Provide wetting and connectivity with medium-level benches, point bars and riparian zone. Maintain water quality.	Commence-to-flow to achieve this not known. This part of the river is used extensively for recreation. Flows of 1,400–2,870 ML/d at Boggabri between Sep–Dec for a minimum of 7 days are required to support native fish spawning/recruitment.
		Wet	Provide wetting and connectivity with higher level benches, point bars and riparian zone. Maintain water quality.	Commence-to-flow to achieve this not known. This section of the river is used extensively for recreation. Flows of 1,400–2,870 ML/d at Boggabri between Sep—Dec for minimum of 7 days are required to support native fish spawning/recruitment.
	Namoi River u/s of Mollee Weir	Extreme dry	No water delivered under extremely dry conditions.	None. Water requirements are likely to be met by other regulated releases.
		Dry	Provide in-stream refuges, aquatic habitat and maintain water quality, in-channel geomorphic structure and organic matter inputs.	Contribute between 1,600–8,000 ML to maintain flows at 1,600 ML/d for 1 to 5 days at Narrabri gauge (commence-to-flow 1,600 ML/d). As above.
		Median	Wet in-stream low-level benches and maintain water quality.	Contribute between 2,000–10,000 ML to maintain flows at 2,000 ML/d for 1 to 5 days at Narrabri gauge (commence-to-flow >1,600 ML/d).
		Wet	Environmental water delivered to wet floodplain assets and maintain water quality.	Contribute between 8,200–41,000 ML to maintain flows at 8,200 ML/d for 1 to 5 days at Narrabri gauge (commence-to-flow 8,200 ML/d).

Asset	WMA	Climate scenario (from Table 5)	Asset environmental watering objective[1]	Environmental water order[2]
Boggabri to Wee Waa	Anabranches from Mollee Weir to Gunidgera Weir	Extreme dry	No water delivered under extremely dry conditions.	None. Water requirements are likely to be met be other regulated releases.
		Dry	Contribute to baseflow to maintain in-stream refuges, aquatic habitat and water quality. Provide wetting and connectivity with low-level benches.	Baseflow is likely to be provided by other regulated releases. To provide wetting of benches and connectivity a total volume of 4,000–20,000 ML may be required to maintain flows at 4,000 ML/d for 1 to 5 days d/s Mollee Weir (commence-to-flow 4,000 ML/d).
		Median	Provide wetting and connectivity with low-level benches, point bars and riparian zone. Maintain water quality.	Contribute between 4,000–55,000 ML to maintain flows at 4,000–11,000 ML/d for 1 to 5 days d/s Mollee Weir (commence-to-flow 4,000–11,000 ML/d).
		Wet	Environmental water delivered to support riparian vegetation, floodplain red gum woodland and wet mid-level benches and point bars. Maintain water quality.	Contribute between 4,000–55,000 ML to maintain flows at 4,000–11,000 ML/d for 1 to 5 days d/s Mollee Weir (commence-to-flow 4,000–11,000 ML/d)
	Barbers Lagoon	Extreme dry	No water delivered under extremely dry conditions.	None. Water requirements are likely to be met by other regulated releases.
		Dry	Contribute to baseflow to maintain refuges and aquatic habitat. Provide wetting and connectivity with low-level benches.	Baseflow requirements are likely to be met by other regulated releases. Contribute between 4,600–23,000 ML to maintain flows at 4,600 ML/d for 1 to 5 days at Boggabri gauge (commence-to-flow 4,600 ML/d). Flows of >4,600 ML/d are required at Boggabri to inundate low commence-to-flow wetlands.
		Median	Provide wetting and connectivity with low-level benches, point bars and riparian zone.	As above.
		Wet	Provide wetting of riparian zone and floodplain red gums.	Contribute between 5,000–25,000 ML to maintain flows at 5,000 ML/d for 1 to 5 days at Boggabri gauge (commence-to-flow >4,600 ML/d). Flows of >4,600ML/d are required at Boggabri to inundate low commence-to-flow wetlands.

Asset	WMA	Climate scenario (from Table 5)	Asset environmental watering objective[1]	Environmental water order[2]
Wee Waa to Walgett	River channel	Extreme dry	Contribute to baseflow to maintain in-stream refuge, aquatic habitat and water quality.	Up to 24 ML/d is required to maintain in-stream refuge, aquatic habitat and end-of-system flows. The current estimates of 75% of the natural 95th percentile daily flow in the Namoi River at Walgett are 21 ML/d in June, 24 ML/d in July, and 17 ML/d in August.
		Dry	Contribute to baseflow to maintain in-stream refuges, aquatic habitat and water quality. Provide wetting and connectivity with low-level benches and point bars. Increase end-of-system flow to Barwon-Darling.	Contribute between 1,900–9,500 ML to maintain flows at 1,900 ML/d for 1 to 5 days at Bugilbone gauge (commence-to-flow 1,900 ML/d). Flows of >4,500ML/d at Bugilbone are required to inundate low commence-to-flow wetlands. Flow target to meet low-flow targets for native fish is 105 ML/d at Wee Waa. Flow target to meet high-flow targets for native fish is 260 ML/d at Wee Waa. Flows of between 8,000–9,000 ML/d for 5 days between Sep-Dec at Wee Waa provide fish passage over weirs.
		Median	Contribute to baseflow to maintain in-stream refuges, aquatic habitat and water quality. Provide wetting and connectivity with low-level benches and point bars. Increase end-of-system flow to Barwon-Darling.	Contribute between 4,500–22,500 ML to maintain flows of 4,500 ML/d for 1 to 5 days at Bugilbone gauge (commence-to-flow 4,500 ML/d). Flows of over >4,500 ML/d at Bugilbone is required to inundate low commence-to-flow wetlands. Flows of 1,550–3,150 ML/d at Wee Waa between Sep–Dec for minimum of 7 days are required to support native fish spawning/recruitment. Flow target to meet high-flow targets for native fish is 260 ML/d at Wee Waa. Flows of between 8,000–9,000 ML/d at Wee Waa provide fish passage over weirs. Timing is for 5 days between Sep–Dec. End-of-system flows increase in addition to that above, if any required.

Asset	WMA	Climate scenario (from Table 5)	Asset environmental watering objective[1]	Environmental water order[2]
Wee Waa to Walgett	River channel	Wet	Contribute to baseflow to maintain in-stream refuges, aquatic habitat and water quality. Provide wetting and connectivity with low-level benches and point bars. Increase end-of-system flow to Barwon-Darling.	Contribute between 6,300–31,500 ML to maintain flows of 6,300 ML/d for 1 to 5 days at Bugilbone gauge (commence-to-flow 6,300 ML/d). Flows of 1,550–3,150 ML/d at Wee Waa between Sep–Dec for minimum of 7 days are required to support native fish spawning/recruitment. Flow target to meet high-flow targets for native fish is 260 ML/d at Wee Waa. Flows between 8,000–9,000 ML/d at Wee Waa provide fish passage over weirs. Timing is for 5 days between Sep–Dec. Contribute between 14,000–70,000 ML to maintain flows at 14,000 ML/d for 1 to 5 days at Bugilbone gauge (commence-to-flow 14,000 ML/d). End-of-system flow increase in addition to that above, if any required.
	Duncans Warrnambool	Extreme dry	No water delivered under extremely dry conditions.	
		Dry	Provide wetting and connectivity with low-level benches and point bars. Maintain water quality.	Contribute between 4,000–20,000 ML/d to maintain flows at 4,000 ML/d for 1 to 5 days at Bullawa gauge (commence-to-flow 4,000 ML/d).
		Median	Provide wetting and connectivity with low-level benches, point bars and riparian zone. Maintain water quality.	Contribute between 4,500–22,500 ML/d to maintain flows at 4,500 ML/d for 1 to 5 days at Bullawa gauge (commence-to-flow >4,000 ML/d at Bullawa).
		Wet	Provide wetting and connectivity with higher level benches, point bars and riparian zone. Maintain water quality.	Contribute between 5,500–27,500 ML/d to maintain flows at 5,500 ML/d for 1 to 5 days at Bullawa gauge (commence-to-flow >4,000 ML/d).
Pian Creek	Channel	Extreme dry	Contribute to baseflow to maintain in-stream refuges, aquatic habitat and water quality.	Current baseflow will achieve extreme dry objectives. Arrangements are for two replenishment flows per water year, not exceeding a combined total volume of 14,000 ML, to provide a visible flow 5 or more consecutive days at Waminda gauge. The flows are provided not more than 7 months apart.
		Dry	Contribute to baseflow to maintain in-stream refuge, aquatic habitat and water quality. Provide wetting and connectivity with low-level benches.	Current baseflow will achieve dry objectives. Contribute between 2,000–10,000 ML/d to maintain flows at 2,000 ML/d for 1 to 5 days (max. channel capacity 2000 ML/d).
		Median	Maintain water quality. Provide wetting and connectivity with low-level benches, point bars and riparian zone.	As above.
		Wet	Maintain water quality. Provide wetting and connectivity with higher level benches, point bars and riparian zone.	Contribute between 3,000–15,000 ML/d to maintain flows at 3,000 ML/d for 1 to 5 days (max. channel capacity 2,000 ML/d).

Asset	WMA	Climate scenario (from Table 5)	Asset environmental watering objective[1]	Environmental water order[2]
Peel River	River channel—Chaffey Dam to Cockburn River	Extreme dry	Contribute to baseflow to maintain in-stream refuges, aquatic habitat and water quality. Prevent fish stranding and allow biota to complete critical life cycle.	Current minimum releases from Chaffey Dam are 3 ML/d. It is not known if these releases meet the watering objective.
		Dry	Baseflow to maintain in-stream refuges, aquatic habitat and water quality; provide connectivity and freshes. Inundate low-level benches and increase flow variability.	Releases made in accordance with the "Stimulus Flow Rule" (see section 8.5) may meet this objective. The maximum daily release of Chaffey Dam is 1,100 ML/d. Inundation of low level in-stream benches requires flows of approximately 500 ML/d.
		Median	Maintain in-stream refuges, aquatic habitat and water quality; provide connectivity and freshes. Inundate medium-level benches and increase flow variability.	As above. Inundation of higher level benches requires flows of between 1,000 and 4,000 ML/d.
		Wet	Maintain in-stream refuges and water quality; provide connectivity and freshes. Inundate medium-level benches and increase flow variability.	As above. Benches higher in elevation in the reach directly downstream of Chaffey Dam require flows greater than the discharge capacity of dam outlet. Inundation of these occurs only when dam spills. Some benches further downstream require volumes of 2,000–5,000 ML/d to inundate.

6. Governance and planning arrangements

6.1 Delivery partners, roles and responsibilities

The partners involved in environmental water delivery in the Namoi system include:

- NSW Office of Water as the administrators of the Upper and Lower Namoi Water Sharing Plan and its environmental water provisions. There is an informal inter-agency agreement that has resulted in NSW Office of Water being responsible for rules-based environmental water and NSW Office of Environment and Heritage being responsible for discretionary (held) environmental water. However, the latter does not currently apply under the Water Sharing Plans for the Upper and Lower Namoi and the Peel (N Foster (NOW) 2011, pers. comm.)
- NSW Office of Environment and Heritage
- NSW State Water Corporation, as the water-delivery authority, is responsible for operational aspects of the river management and water delivery.

6.2 Approvals, licences, legal requirements and other administrative issues

If NSW water entitlements are to be recognised as Adaptive Environmental Water (AEW) under the *Water Management Act 2000* (NSW), Section 8E (7) of the Act requires NSW AEW access licences to have suitable conditions applied.

The licence holder can choose to commit the licence as adaptive environmental water as well as the associated conditions relating to its delivery. These conditions have to be agreed to by the NSW water minister.

The licence holder can choose to uncommit the licence from AEW conditions at any time, except as provided by the regulations.

The NSW RiverBank program has followed the AEW process and have prepared water use plans for river systems where they hold entitlements, which does not include the Namoi.

Based on the RiverBank Water Use Plans, the following elements are generally included:

- identification of the water source(s)
- aims and objectives of the plan and as they relate to specific sites
- plan area and the locations where water use is authorised
- watering priorities
- conditions of water use including measuring points and works
- rules for accounting water use
- access licence dealing rules
- monitoring, evaluation and amendment requirements
- reporting arrangements
- management responsibilities.

As indicated in section 1.4, there is generally no history for use of held environmental water in the Namoi. Similarly, there is no history or existing governance framework for advice and decision-making on the use of held environmental water. The exception to this is the Peel River Water Sharing Plan, which does allow for some environmental flows once certain inflows are achieved at Chaffey Dam.

Delivery points

Environmental water delivery points for water order accounting purposes are likely to be dependent on the location of the target for environmental water but may include:

- Chaffey Dam—measurement of stimulus flow rule
- Keepit Dam—measurement of bulk water transfers
- Namoi River at Gunnedah (419001)—measurement of flows to Carroll to Boggabri reach
- Namoi River at Narrabri (419002)—measurement of flows to Boggabri to Mollee Weir reach
- Namoi River downstream of Mollee Weir (419039A)—measurement of flows to anabranches from Mollee Weir to Gunidgera Weir
- Namoi River at Bugilbone (419021)—measurement of flows to Wee Waa to Walgett Reach
- Namoi River at Bullawa (419095)—measurement of flows to Duncans Warrambool
- Namoi River upstream of Walgett (419091)—measurement of end-of-system flows
- Pian Creek at Waminda (419049)—measurement of flows to Pian Creek.

6.3 Relevant trading rules and constraints

6.3.1 Water dealings

The Water Sharing Plan for the Upper and Lower Namoi River sets out rules that are relevant to environmental water delivery. These include:

- Restrictions on the volumes of general-security and high-security share components and account water that can be traded into the Gunidgera/Pian system until extraction components have been amended in accordance with clause 47 of the Water Sharing Plan. A dealing is prohibited if it would result in:
  - the total number of unit shares in share components of supplementary water access licences, which nominate water supply works in the Gunidgera/Pian Creek system, exceeding the total number of unit shares at the commencement of the Water Sharing Plan; or,
  - the total volume of water allocations assigned to supplementary water access licences, nominating water supply works on the Gunidgera/Pian system exceeding the total volume of water allocations assigned from supplementary water licences, within that system to access licences nominating water supply works not on the Gunidgera/Pian system during the water year.
- Other water dealings which are prohibited on the Namoi River include:
  - the assignment of water allocations from a supplementary water access account to or from an access licence of any other access licence category
  - any dealing that results in an increase in the total share components of high-security access licences nominating water supply works downstream of the Namoi River at Mollee Weir.
- The ability to transfer share components between the upper Namoi and lower Namoi water sources and other water sources, although conversion factors and other rules may apply. Rules for transferring between water sources include that:
  - the access-licence dealing rules in the other water source permit such a dealing
  - a conversion factor that protects environmental water, domestic and stock rights, native title rights and the reliability of supply to all other access licences in these water sources has been applied
  - the share component of a new access licence issued is to be equal to the share component of the cancelled access licence.
- Rules specifically relating to water allocation assignments between Split Rock and Keepit Dam include that:
  - Water allocations cannot be assigned from the water allocation account of an access licence in the Upper Namoi Regulated River Water Source to the Lower Namoi Regulated River Water Source if there is a significant risk that the rate at which water can be released from Keepit Dam water storage during the remainder of the water year will be insufficient to meet likely water orders.
  - The assignment of water allocations from access licences in the Lower Namoi Regulated River Water Source to access licences in the Upper Namoi Regulated River Water Source is prohibited unless the sum of available water determinations made for general security access licences in the Upper Namoi Regulated River Water source during the water year is equal to the maximum percentage permissible under available water determinations and there is sufficient water available in Split Rock Dam to supply the assigned water allocations.

These restrictions may not be applicable in relation to environmental uses of water, but would need to be reviewed if it was intended to use water in these lower reaches.

Rules relating to water allocations and dealings in the Peel River that may be relevant to environmental water delivery include that:

- the sale, rental or transfer of the ownership of an access licence is permissible
- sale of the share or extraction component (see WMA 2000, section 56) of an access licence is allowed, as is the sale of account
- the conversion of an access licence is permitted
- change in the location from which a water access licence can extract water from a water source is also permissible.

6.3.2 Operations

Operational considerations which may impact on water availability and delivery include that sufficient volumes of water must be set aside from assured inflows into Split Rock Dam, Keepit Dam or other water storages to provide replenishment flows of up to a total volume of 14,000 megalitres in any water year to Pian Creek downstream of Dundee Weir.

Another operational consideration are bulk transfers which occur between Split Rock and Keepit Dam. Rules associated with these transfers and their possible impact on environmental water delivery are described in section 8.4.

7. Risk assessment and mitigation strategies

Risks associated with the delivery of environmental water in the Namoi catchment are summarised in Table 11. 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. A matrix for assessing risks has been developed by SEWPaC and is included at Appendix 6.

Table 11: Risk associated with environmental water delivery in the Namoi catchment

Risk	Description	Likelihood	Consequence	Risk level	Mitigation
Water quality					
Salinity	Salinity, particularly in relation to floodplains, is considered a major issue in the Namoi catchment (Thoms et al. 1999). Delivering environmental water to floodplains could result in salt mobilisation. Salinity may also increase in weir pools during low flow or no flow periods.	Possible	Moderate	Medium	Continued investigation and monitoring of the impact of environmental water on floodplains. Information should be incorporated through adaptive management. Continuous flows during summer months.
Blue-green algae	Blue-green algal blooms may occur during low-flow periods (N Foster (NOW) 2011, pers. comm.).	Possible	Moderate	Medium	Maintaining flows during summer months could reduce the risk of these events occurring. There should be regular monitoring and a warning system in place.
Blackwater	Blackwater events may occur with the release of water after prolonged dry or low-flow periods where there has been build-up of organic material in channels and on floodplains. Blackwater events have not been recorded for the Namoi River.	Unlikely	Major	Medium	Delivery of flows during cooler months may reduce the likelihood of blackwater events. Dilution flows may also reduce blackwater impacts. Monitoring responses to inflows entering previously dry areas is also required to inform management actions.
Hydrology					
Flooding of infrastructure	Flooding and isolation of properties, roads and irrigation pumps during environmental water delivery. The maximum release rate from Keepit Dam is within the river channel capacity and very unlikely to result in adverse flooding. The use of piggybacking onto unregulated flows may present some risk, therefore any additional environmental water delivery must remain below flood thresholds.	Rare	Moderate	Medium	Ensure water levels do not exceed flooding thresholds; communicate increases in water level to landholders and local councils.
Streambank/ channel erosion	Delivery of environmental water may result in erosion of stream banks and channels, particularly if rapid changes in water level occur.	Likely	Moderate	Medium	Design water delivery profile to avoid impacts on stream banks and channels.

Risk	Description	Likelihood	Consequence	Risk level	Mitigation
Water loss/ inefficient delivery	Water delivery to the lower Namoi River may result in significant losses during transmission. This may result in a reduction in inundation area or duration, thereby not meeting environmental water objectives.	Likely	Moderate	Medium	Timing delivery to coincide with operational flows in late winter/early spring will generally reduce losses.
Ecology					
Cold water releases	Cold water release from Keepit Dam is known to affect the downstream environment for at least 100 kilometres.	Likely	Moderate	Medium	The dam is being upgraded to include a multi-level off-take to reduce this impact. Completion expected 2013.
Inappropriate inundation of floodplain vegetation	Floodplain inundation of inappropriate duration resulting in the drowning or drying of vegetation.	Possible	Moderate	Medium	Monitor and adjust floodplain inundation regimes as required.
Invasive species	Carp have been identified as a major pest species in the Namoi River and breeding may be supported by environmental flows.	Likely	Moderate	Medium	Ensure the timing of water delivery favours native fish species. NSW Fisheries to provide support.
	Lippia presents an environmental threat and is found in most wetlands and riparian areas throughout the Namoi catchment. It can cause severe bank erosion, degradation of soil and water and displacement of native plant species. It is difficult to control once established (Mawhinney 2004).	Likely	Moderate	Medium	Inundation of wetlands for appropriate length of time to 'drown' lippia. Promote complementary land management practices (e.g. grazing regime) that may assist in protecting native vegetation.
Drowning platypus burrows	The bulk water transfer between Split Rock and Keepit Dam may threaten platypus burrows.	Possible	Moderate	Medium	Ensure bulk water transfer undertaken prior to the platypus nesting season.
Fish stranding	Cease to flow within river and creek channels or rapid fall in wetland water levels can lead to fish strandings, which may significantly reduce fish populations.	Possible	Major	High	Manage flows to prevent weir pool drying.
Climatic					
Climate variability	Rainfall and inflows are highly variable in the Namoi catchment, resulting in unpredictable flow rates. Climate change is likely to increase frequent extreme weather conditions, such as drought.	Possible	Moderate	Medium	Watering options to take into account best available weather models/information.

8. Environmental water reserves

8.1 Environmental water provisions and holdings

Environmental water entitlements for the Namoi River are summarised in Table 12.

Table 12: Environmental water entitlements on the Namoi River

Holder	High security	General security
Commonwealth	0	Upper Namoi—105 ML Lower Namoi—6,098 ML
NSW	0	0
Others	0	0

8.2 Available water determinations and seasonal allocations

The NSW Office of Water administers the following rules of the Water Sharing Plan for high and general-security entitlements with assistance from State Water.

In the upper Namoi and lower Namoi River, available water determinations are made for each access licence category at the start of the water year and, if required, during the course of the year. The water made available to high-security licences is 1 megalitre per one unit share in all but exceptional drought years. Available water determinations for general security access licences in the upper Namoi River vary from year-to-year depending upon the amount of water held in Split Rock Dam and whether more water becomes available during the year. The water made available to general security access licences in the lower Namoi River is reviewed monthly and depends upon the amount of water held in Split Rock and Keepit Dams. Updates on available water determinations in the Namoi Valley are available from the NSW Office of Water at: http://registers.water.nsw.gov.au/wma/DeterminationSearch.jsp?selectedRegister=Determination.

8.3 Storage accounting and carryover rules

Different rules apply to water accounts on the upper and lower Namoi River. These were presented in Table 5 and are described in the following section.

The accounts of all high security, stock and domestic and local water utility licences in the upper Namoi River are managed on an annual basis. Water remaining in an account at the end of each water year is forfeited, with the account receiving a new allocation of water in the next water year. The limit to available water determinations for these access licences is 100 per cent or 1 megalitre per unit share.

General security access licences in the upper Namoi River are managed on an annual allocation with carryover basis. Carryover of unused allocation of up to 0.5 megalitres per unit share is permitted with an account limit of 1 megalitre per unit share at any time.

Extraction of uncontrolled flows without debit to the account is permitted when the sum of the available water determinations are equal to or less than 0.6 of a megalitre per unit share.

For the lower Namoi River, the maximum volume that may be held in high-security, local-water utility and stock-and-domestic access licence accounts is equal to 1 megalitre per unit share and water cannot be carried over from one water year to the next.

For general-security licences in the lower Namoi River, continuous accounting rules apply and carryover is allowed for any water remaining in the account from one water year to the next. The maximum volume that may be held in the water account of a general-security access licence in the lower Namoi River, at any time, is equivalent to 2 megalitres per unit share. The maximum volume in the lower Namoi River that may be extracted under a general-security access licence or assigned from it in any water year is limited to 1.25 megalitres per unit share, or 3 megalitres per unit share over any consecutive three years. These limits can be increased by water allocations assigned from another access licence.

For Chaffey Dam, high-security access licences and other high-priority licence categories (e.g. stock and domestic, local-water utilities) for the regulated river provide allocations equal to 100 per cent of the share component volume in all but exceptional drought years. Available water determinations for general-security access licences in the regulated river are made per unit share, and dependent on the resources available in the dam at the start of the year. Further available water determinations may be made throughout the water year following subsequent inflows into the dam. A maximum available water determination for regulated Peel River licences of less than 1 megalitre per unit share may also be made if average extraction in previous years exceeds the long-term average annual extraction limit (LTAAEL).

In the regulated Peel River, no carryover is permitted and accounts are managed on an annual basis with the maximum use limited to the allocations accrued each water year. General-security access licences also have access to no-debit water from uncontrolled unregulated and environmental flows in the regulated river. The use of no-debit water plus the allocation in their accounts is limited to the maximum available water determination in that water year for these licences.

8.4 Bulk transfer rules between Split Rock and Keepit Dams

The following information is provided on bulk transfer rules, as on occasions a proportion of the Australian Government's water allocations for the lower Namoi River will be held in Split Rock Dam. Bulk transfers provide an opportunity for Commonwealth environmental water to be transferred from Split Rock Dam to Keepit Dam in a manner that provides environmental benefits to the riverine environment between the two storages. Rules associated with the transfer include that:

- any bulk transfer of water from Split Rock Dam water storage to Keepit Dam water storage should be carried out in a manner that minimises adverse environmental impacts
- prior to making any bulk transfer from Split Rock Dam water storage to Keepit Dam water storage the NSW water minister should:
  - determine an appropriate pattern of release from Split Rock Dam, taking into consideration the volume and time requirements of the bulk transfer and the need to minimise downstream environmental impacts
  - consult with water users on the upper Namoi and Manilla rivers regarding the pattern of release
  - provide a minimum of 14 days notice of the intended release to water users between Split Rock Dam and Keepit Dam water storage
  - conduct appropriate monitoring
  - advise the community regarding the intended water releases through media releases.

8.5 Chaffey Dam Stimulus Flow Rule

Environmental release rules for the Stimulus Flow (as described in section 1.5.2) from Chaffey Dam are outlined in Appendix 1. A summary of these rules prior to the storage capacity increasing to 100,000 megalitres include:

- The volume of water in Chaffey Dam at the start of the water year must be greater than 50,000 megalitres before the next 1,600 megalitres of inflows are set aside for the purpose of releasing a stimulus flow.
- If the volume of water in the dam at the start of the water year is equal to or less than 50,000 megalitres then, when it increases to more than 50,000 megalitres, the next 1,600 megalitres of inflows will be set aside for the purpose of a stimulus flow.
- Stimulus flows should be released from Chaffey Dam between 1 July and 31 August or between 1 March and 30 June in the following calendar year, if a flow of 500 ML/d or more has not occurred in the Peel River at Piallamore in the preceding 90 days.
- A stimulus flow release should continue for a period of seven days with a total volume of 1,600 megalitres and a peak of 500 ML/d occurring on the second day.
- Extraction of the stimulus flow under general-security access licences is permitted under the conditions stipulated in the Water Sharing Plan (see Appendix 1).

Following the enlargement of Chaffey Dam, an environmental contingency allowance (ECA) will be set aside in the storage and managed in accordance with the following rules (see Appendix 1 for details):

- An account of the ECA water is to be kept.
- Whenever an available water determination for general security is made, a volume of water equivalent to 5,000 megalitres multiplied by the available water determination should be allocated to the ECA account.
- Water in the ECA account should be released to return some of the natural flow variability to the upper reaches of the Peel River.
- Where the capacity to release water from Chaffey Dam is insufficient to meet all water requirements, then access-licence water orders shall have priority.
- The ECA account will be deducted by an amount equal to the volume of water released from Chaffey Dam, and any unused water remaining in the ECA account at the end of the water year cannot be carried over.
- Extraction of the stimulus flow under general security is permitted under the conditions stipulated in the Water Sharing Plan (see Appendix 1).

Under stimulus flow rules a minimum daily release of 3 megalitres is required to be delivered downstream of Chaffey Dam.

PART 3:
Monitoring and future options

9. Monitoring, evaluation and improvement

A number of hydrological and ecological monitoring programs are operating throughout the Namoi catchment. Further detail is provided below.

9.1 Current monitoring and reporting

9.1.1 Water quality and ecological reporting

Routine monitoring

The NSW Office of Water carries out monitoring of basic water quality indicators such as nutrient and algae across the Namoi catchment. Water quality monitoring programs include the:

- Key Sites Program, which monitors basic water quality variables at sites across the state
- Central and North West Water Quality Monitoring Program
- Storage Water Quality Program
- some pesticide monitoring throughout the catchment.

Both river and storage water quality information can be found on the NSW Water Information Site which also includes continuous electrical conductivity monitoring at five sites throughout the Namoi catchment: http://waterinfo.nsw.gov.au/wq/namoi.shtml

Intervention/hypothesis-based monitoring

Further to the water quality monitoring undertaken by the NSW Office of Water, the Integrated Monitoring of Environmental Flows (IMEF) program commenced in the Namoi catchment in 1997 and ceased in 2011. This program, supported by NSW Fisheries and researchers, assessed the ecological benefits of the environmental flow rules. The objectives of the IMEF program were:

- to investigate relationships between water regimes, biodiversity and ecosystem processes in the major regulated river systems, and the Barwon-Darling River
- to assess responses in hydrology, habitats, biota and ecological processes associated with specific flow events targeted by environmental flow rules
- to use the resulting knowledge to estimate likely long-term effects of environmental flow rules and provide information to assist in future adjustment of rules.

Within the Namoi catchment, the IMEF program specifically investigated the benefit of environmental flows for wetland habitat and biodiversity in the Namoi River. The IMEF carbon hypothesis, conducted within the Namoi catchment, focused on the role that wetting of riparian litter may play in stimulating riverine food webs (DWE 2008). Environmental flows may increase the amount of dissolved organic carbon (DOC) entering river environments by transporting DOC associated with benches and floodplains to the river (DWE 2008). It proposed that those flow rules that protect a proportion of freshes and high flows will result in more frequent wetting of river banks, benches and floodplains, increasing transport of DOC into the river system and so support aquatic food chains. Results obtained during flooding showed that the wetting of riparian zones and floodplains can inject substantial quantities of DOC into aquatic ecosystems.

Mapping and assessments

Namoi CMA has also been involved in a number of studies including the assessment and prioritisation of wetlands within the Namoi catchment. Their investigations included comprehensive mapping of wetlands from satellite imagery, wetland inundation assessment and the development of a prioritisation and monitoring framework (Hale et al. 2006; Eco Logical 2008).

Another study was commissioned by the Namoi CMA and the Cotton Catchment Community CRC to develop a framework for evaluating and mapping the condition of native riparian and floodplain vegetation in the Namoi catchment. This framework measured vegetation condition using a combination of landscape metrics derived from remotely sensed data and a sampling program capturing ecological data. These metrics were then rated against established benchmarks to identify and prioritise areas for protection and restoration (Eco Logical 2009).

9.1.2 Sustainable Rivers Audit

The MDBA's Sustainable Rivers Audit (SRA) is a systematic assessment of the health of river ecosystems in the Basin. It is overseen by a panel of independent ecologists (the Independent Sustainable Rivers Audit Group (ISRAG)) and carried out by a number of agencies including NSW Office of Water and Industry and Investment NSW. Quantitative information on environmental indicators is collected at pre-determined sites within valleys throughout the Basin. The indicators provide baseline and trend information for particular components of the river ecosystems. The first stage of the SRA used three themes: hydrology, fish and macroinvertebrates.

The SRA studies have found that overall, the Namoi catchment was generally in a poor condition; see http://www.mdba.gov.au/sustainable-rivers-audit/. The SRA fish assessment rated the catchment in poor condition in terms of native fish populations, with 12 native and five alien fish species captured. Macroinvertebrate condition was also poor in the Namoi River. In contrast the hydrological condition was assessed as good through all zones, but there had been changes in volume, seasonality and high flows in response to regulation and diversions (Davies et al. 2008).

The next SRA report is currently in preparation and will use five themes to assess the health of river ecosystems. These are hydrology, fish, macroinvertebrates, vegetation and physical form.

9.1.3 Hydrological monitoring, reporting and modelling

NSW Office of Water has an extensive hydrographic network which records river water levels and flows, storage elevations, volumes and discharges and continuously monitors electrical conductivity from locations across New South Wales. This provides critical information which is used to determine and define the flow characteristics of watering events.

The Integrated Quantity and Quality hydrological model (IQQM) has been developed to support water-management planning, including the allocation and management of environmental water. IQQM runs simulate 'undeveloped' long-term flow conditions as well as current river-flow scenarios.

CSIRO, in collaboration with other groups, has been developing and linking hydrological models to provide support for integrated surface water planning across the Basin, including modelling of river flows and water availability to support MDBA planning. CSIRO has linked models to assist the MDBA to evaluate alternative scenarios and has included environmental water demands in the models.

9.2 Operational water delivery monitoring

As explained in the previous section and section 1.8, the NSW Office of Water has an extensive hydrographic network that provides critical information used to determine and define the flow characteristics of watering events. A description of the network and available data is given in the NSW Strategic Water Information Monitoring Plan (NOW 2011), and is available on the NSW Office of Water website at: http://www.water.nsw.gov.au/.

Gauging stations on the Namoi River that are likely to be used as accounting points and that can provide information to inform water delivery are detailed in section 6.2.

The Department of Sustainability, Environment, Water, Population and Communities has developed a pro forma operational monitoring report for use in environmental watering actions (see Appendix 7).

9.3 Possible monitoring and reporting

Table 13 lists possible monitoring options to measure and report on environmental watering of assets included in this document.

Table 13: Possible monitoring options for environmental watering

River system	WMA	Ecological and/or hydrological objective	Hypotheses	Flow component	Indicator(s)	Monitoring sites	Frequency	Linkages and other considerations
Namoi	Whole of river channel	Provide fish refuge during low-flow periods.	Low-flow channels within confines of larger Namoi channel will support native fish species during low/no-flow periods.	Baseflow	Native fish abundance and diversity.	Key fisheries sites associated with proposed monitoring actions.	To coincide with low flows.	Complement monitoring undertaken by NSW Fisheries.
	Split Rock to Keepit Dam	Maintain in-stream refuges and aquatic habitat.	Freshes will inundate benches and increase connectivity, benefiting refuges and in-stream habitat.	Medium to high flows.	Water level; energy transfer.	Existing NOW sites plus complementary sites.	Prior to, during and following bulk environmental water transfers.	Complement existing NOW and State Water monitoring programs.
	Whole of river channel	Provide habitat and breeding opportunities for native fish.	Sufficient flows will provide habitat and breeding opportunities for native fish.	Under all flow conditions.	Native fish abundance, diversity and, condition. Successful breeding events.	Existing NSW Fisheries' sites.	1–3 years	Existing NSW Fisheries' monitoring.
	Lower Namoi floodplain	Transport of sediments, nutrients and energy. Unrestricted movement of aquatic biota.	Hydrologic connectivity through the periodic inundation of anabranches and floodplain wetlands will achieve energy exchange and allow movement of aquatic biota.	Medium-to-high flows.	Water level and timing, magnitude and flow frequency. Inundation area (mapping).	Anabranch and wetland sites.	Flow-dependent	NOW and community monitoring.

River system	WMA	Ecological and/ or hydrological objective	Hypotheses	Flow component	Indicator(s)	Monitoring sites	Frequency	Linkages and other considerations
Namoi	Channels and anabranches	Maintain or improve water quality.	Appropriate flow management will assist in maintaining and/or improving water quality.	Under all flow conditions.	Physicochemical responses to environmental flows.	Existing NOW water quality sites. Existing IMEF sites.	Dependent on season and inundation.	NOW, State Water quality sampling.
	Floodplain vegetation	Maintain and/or enhance floodplain vegetation and support waterbird populations.	Appropriate flow regimes will assist in maintaining or improving floodplain vegetation (e.g. river red gum, black box, Coolibah) provide important feeding, breeding and refuge habitats.	Under all flow conditions.	The condition and extent of floodplain vegetation communities.	Existing or previously investigated sites and key water delivery targets.	Pre and post-inundation	Previous NOW and Namoi CMA funded studies.
	Floodplain wetlands	Provide habitat and breeding opportunities for frogs.	Sufficient depth and extent of inundation that will provide habitat and breeding opportunities for frogs.	Moderate-to-high flows.	Frog abundance, diversity and condition. Successful frog breeding events.	Floodplain wetland sites.	Inundation events.	Existing OEH monitoring.
Peel	Channel	Provide connectivity and freshes.	Freshes will inundate benches and increase connectivity.	Medium-to-high flows.	Water level; energy transfer.	Existing NOW sites.	Prior to, during and following releases.	Complement existing NOW and State Water monitoring programs.

10. Operational constraints and opportunities

10.1 General

The operational constraints for delivering water in the lower parts of the Namoi catchment are largely covered in previous sections, however, the following points should be re-emphasised:

- the maximum release from Chaffey Dam is currently 1,100 ML/d
- the Namoi channel can accommodate a maximum release of 3,500 ML/d from Keepit Dam
- the maximum channel capacity of Pian Creek is estimated at 2,000 ML/d
- Gunidgera off-take, which regulates flows into Pian Creek, has a capacity of 1,250 ML/d
- volumes of general and high-security share components and account water that can be traded into the Gunidgera/Pian system are currently restricted
- Weeta Weir, which has a capacity of 280 megalitres, cannot be used for storage due to on-going problems. It has been decommissioned and will not be used for re-regulatory purposes.

10.2 Opportunities

As previously outlined, while there is a stimulus flow of up to 1,600 megalitres available in the Peel River under certain inflow conditions, there is no held planned environmental water in the Namoi River under the current Water Sharing Plan. However, the protection of flows above the long-term average extraction and minimum flows at Walgett during June, July and August provide some opportunity to piggyback flows with environmental water. This may allow the delivery of pulsed freshes to inundate benches and anabranches.

There is also the opportunity to use environmental water to improve end-of-system flows at Walgett and therefore improve some of the flow-related dependent ecology of the Barwon-Darling River. Under the Water Sharing Plan it is a requirement to supply an end-of-system flow at Walgett during the months of June, July and August when the combined volume at Keepit Dam and Split Rock Dam is greater than 120,000 megalitres. CSIRO (2007) have given a 'best' estimate that there would be a 5 per cent reduction in water availability and an 8 per cent reduction in end-of-system flows under a 2030 climate scenario. As such, environmental water may provide an opportunity to increase end-of-system flows. This could be achieved through piggybacking on unregulated flows, increasing the height or extending the length of freshes, thereby wetting benches, increasing connectivity or extending wetting duration.

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Appendix 1
Environmental flow rules for the Peel River

The information below has been taken from the *Water Sharing Plan for the Peel Regulated, Unregulated, Alluvial and Fractured Rock Water Sources 2010* (NSW). This plan commenced on 1 July 2010. (References to 'the Act' are to the *Water Management Act 2000* (NSW)).

1. Until the storage capacity of Chaffey Dam has been enlarged to 100,000 megalitres the following rules shall apply:
   - if at the start of a water year the volume of water in Chaffey Dam water storage is greater than 50,000 megalitres, then the next 1,600 megalitres of inflows to Chaffey Dam shall be set aside in Chaffey Dam for the purpose of releasing a flow called a stimulus flow from Chaffey Dam;
   - if at the start of a water year the volume of water in Chaffey Dam water storage is equal to or less than 50,000 megalitres then the first time during that water year the volume of water in Chaffey Dam water storage increases to more than 50,000 megalitres, then the next 1,600 megalitres of inflows to Chaffey Dam shall be set aside for the purpose of releasing a flow called a stimulus flow from Chaffey Dam;
     a. after 1,600 megalitres has been set aside under paragraph (a) or (b) for a stimulus flow, it shall be released from Chaffey Dam between 1 July and 31 August or between 1 March and 30 June in the following calendar year, if a flow of 500 ML/d or greater has not occurred in the Peel River at Piallamore in the preceding 90 days;
     b. a stimulus flow release made under paragraph (c) should continue for a period of seven days with a total volume of 1,600 megalitres and a peak of 500 ML/d occurring on the second day; and
     c. extraction of the stimulus flow under regulated river (general security) access licences is permitted to the extent specified in clause 62.
2. After the storage capacity of Chaffey Dam has been enlarged to 100,000 megalitres or greater, an environmental contingency allowance (hereafter ECA) is to be set aside in Chaffey Dam water storage and managed in accordance with the following:
   - an account of the ECA water that is set aside in Chaffey Dam is to be kept;
   - whenever an available water determination for regulated river (general security) access licences is made, a volume of water in megalitres that is equivalent to 5,000 multiplied by that available water determination shall be allocated to the ECA account;
   - water in the ECA account shall be released to return some of the natural flow variability to the upper reaches of the Peel River which have been adversely affected by river regulation;
   - where the capacity to release water from Chaffey Dam is insufficient to meet the ECA release requirements plus access licence water orders for that same day then access licence water orders shall have priority;
   - the ECA account shall be deducted with a volume of water equal to the amount released from Chaffey Dam under paragraph (c);
   - any unused water remaining in the ECA account at the end of the water year cannot be carried over to the following water year; and
   - extraction of ECA releases under regulated river (general security) access licences is permitted to the extent specified in clause 62.

3. A minimum daily release will be made from Chaffey Dam that is equal to 3 megalitres except when a release of greater than 3 ML/d is required to meet basic landholder rights and access licence extractions or when a release is being made under subclauses (1) or (2).

Section 62: Taking of uncontrolled flows, stimulus flow and ECA releases under regulated river (general security) access licences

1. An order under section 85A of the Act may only be made for a regulated river (general security) access licence nominating metered water supply works and must be made in accordance with the provisions of this clause.
2. An order under section 85A of the Act and subclause (1) may authorise the taking of water from uncontrolled flows that arise from:
   a. unregulated inflows to the water source, or
   b. stimulus flow or ECA that has been released from Chaffey Dam, and that have not been credited to a regulated river (general security) access licence water allocation account in the Peel Regulated River Water Source.
3. The following rules apply to the taking of uncontrolled flows that arise from unregulated inflows to the water source under subclause (2) paragraph (a):
   a. announcements may be made by the NSW Office of Water for the following sections of the water source only:
      (i) Chaffey Dam to Paradise Weir,
      (ii) Paradise Weir to Attunga Creek, and
      (iii) Attunga Creek to the Namoi River,
   b. when the sum of available water determinations for regulated river (general security) access licences in the Peel Regulated River is less than 0.35 megalitres per unit of share component in the water year, then the taking of water from uncontrolled flows shall:
      (i) only be permitted to commence when the uncontrolled flow in the Peel River at Caroll Gap is equal to or greater than 40 ML/d, and
      (ii) cease within each section of the water source specified in subclause (3) paragraph (a) when the uncontrolled flow in the Peel River at any river gauging station within the respective section falls below 5 ML/d, and
   c. when the sum of available water determinations for regulated river (general security) access licences in the Peel Regulated River is equal to or greater than 0.35 megalitres per unit of share component in the water year, then the taking of water from uncontrolled flows shall:
      (i) only be permitted to commence when the uncontrolled flow in the Peel River at Caroll Gap is equal to or greater than 50 ML/d,
      (ii) cease when the uncontrolled flow in the Peel River at Caroll Gap is less than 50 ML/d.

4. The following rules apply to the taking of uncontrolled flows that arise from stimulus flow or ECA that has been released from Chaffey Dam under subclause (2) paragraph (b):

   a. announcements may be made by the NSW Office of Water for the following sections of the water source only:

      (i) Chaffey Dam to Piallamore gauging station, and

      (ii) downstream of Piallamore gauging station to the Namoi River,

   b. the taking of water from uncontrolled flows that arise from stimulus flow or ECA between Chaffey Dam and Piallamore gauging station shall:

      (i) only be permitted to commence when the stimulus flow or ECA water is equal to or greater than 50 ML/d at Piallamore gauging station, provided the water taken is used to directly irrigate crops and is not pumped into an on-farm storage, and

      (ii) cease when the stimulus flow or ECA water is less than 50 ML/d at Piallamore gauging station,

   c. when the sum of available water determinations for regulated river (general security) access licences in the Peel Regulated River is less than 0.35 megalitres per unit of share component in the water year, then the taking of water from uncontrolled flows under a regulated river (general security) access licence downstream of Piallamore gauging station shall:

      (i) only be permitted to commence when the uncontrolled flow in the Peel River at Caroll Gap is equal to or greater than a forecast flow rate of 40 ML/d, and

      (ii) cease within each section of the water source specified in subclause (4) paragraph (a) when the uncontrolled flow in the Peel River at any river gauging station within the respective section falls below 5 ML/d, and

   d. when the sum of available water determinations for regulated river (general security) access licences in the Peel Regulated River is equal to or greater than 0.35 megalitres per unit of share component in the water year, then the taking of water from uncontrolled flows under a regulated river (general security) access licence downstream of Piallamore gauging station shall:

      (i) only be permitted to commence when the uncontrolled flow in the Peel River at Caroll Gap is equal to or greater than a forecast flow rate of 50 ML/d, and

      (ii) cease when the uncontrolled flow in the Peel River at Caroll Gap is less than 50 ML/d.

5. In any uncontrolled flow event that arises from unregulated inflows to the water source under subclause (2) paragraph (a), total extraction of uncontrolled flow under subclause (3) in each section of the water source specified in subclause (3) paragraph (a) under regulated river (general security) access licences is not permitted to exceed an amount that is equal to 50 per cent of the forecast uncontrolled flow volume above:

   (i) 5 ML/d of uncontrolled flow as measured at the most downstream gauge for each section of the water source specified in subclause (3) paragraph (a), when the sum of available water determinations for regulated river (general security) access licences in the Peel Regulated River is less than 0.35 of a megalitre per unit of share component in the water year, or

   (ii) 50 ML/d of uncontrolled flow as measured at Caroll Gap, when the sum of available water determinations for regulated river (general security) access licences in the Peel Regulated River is equal to or greater than 0.35 of a megalitre per unit of share component in the water year.

6. In any water year, the total amount of uncontrolled flow that may be taken under each regulated river (general security) access licence is limited to an amount that is equal to the difference between:
   a. the sum of available water determinations for that water year for regulated river (general security) access licences, and
   b. the maximum sum of available water determinations that can be made for regulated river (general security) access licences under Division 2 of Part 7 of this Plan.
7. The amount of uncontrolled flow taken under each regulated river (general security) access licence shall be recorded in the water allocation account of the regulated river (general security) access licence.
8. Regulated river (general security) access licence holders must supply State Water with meter readings taken immediately prior to and after the taking of uncontrolled flow within 7 days of ceasing to take uncontrolled flow.
9. If the total amount of uncontrolled flow extracted under a regulated river (general security) access licence exceeds the limits specified in subclause (6) then a volume equivalent to the exceedance shall be debited from allocations credited to the access licence water allocation account in that water year.

Appendix 2
Water-dependent species of the Namoi River

The following tables list species associated with the Namoi catchment and include their status in relation to the NSW *Threatened Species Conservation Act 1995*, NSW *Fisheries Management Act 1994* and Commonwealth *EPBC Act 1999*.

Table 14: Bird species of significance in the Namoi catchment

Birds					
Common name	Scientific name	EPBC Act listing	NSW status[i]	Wetland dependent[ii]	Presence
Great egret	*Egretta alba or Ardea alba*	Migratory		Yes	Known[iii]
Glossy ibis	*Plegadis falcinellus*	Migratory		Yes	Known
Latham's snipe	*Gallinago hardwickii*	Migratory		Yes	Known
Marsh sandpiper	*Tringa stagnatilis*	Migratory		Yes	Known
Common greenshank	*Tringa nebularia*	Migratory		Yes	Known
Sharp-tailed sandpiper	*Calidris acuminata*	Migratory		Yes	Known
Caspian tern	*Hydroprogne caspia or Sterna caspia*	Migratory		Yes	Known
White-throated needletail	*Chaetura caudacuta or Hirundapus caudacutus*	Migratory		Yes	Known
Clamorous reed-warbler	*Acrocephalus stentoreus*	Migratory		Unknown	Known
Superb parrot	*Polytelis swainsonii*	Vulnerable	Threatened	Breeds in long-lived riverine trees.	Known
Australasian bittern	*Botaurus poiciloptilus*		Vulnerable	Yes	Known[iv]
Barking owl	*Ninox connivens*		Vulnerable		Known
Black-breasted buzzard	*Hamirostra melanosternon*		Vulnerable		Known
Black-necked stork	*Ephippiorhynchus asiaticus*		Endangered	Yes	Known
Black-tailed godwit	*Limosa limosa*		Vulnerable	Yes	Known
Blue-billed duck	*Oxyura australis*		Vulnerable	Yes	Known
Brolga	*Grus rubicunda*		Vulnerable	Yes	Known
Diamond firetail	*Stagonopleura guttata*		Vulnerable	Often found in riparian vegetation.	Known

Birds					
Common name	Scientific name	EPBC Act listing	NSW status[i]	Wetland dependent[ii]	Presence
Freckled duck	*Stictonetta naevosa*		Vulnerable	Yes	Known
Gilbert's whistler	*Pachycephala inornata*		Vulnerable	Unknown	Known
Magpie goose	*Anseranas semipalmata*		Vulnerable	Yes	Known
Painted snipe	*Rostratula benghalensis*		Endangered	Yes	Known
Red goshawk	*Erythrotriorchis radiatus*		Critically endangered		Known
Regent honeyeater	*Xanthomyza phrygia*		Endangered		Known
Grey falcon	*Falco hypoleucos*		Vulnerable		Predicted
Square-tailed kite	*Lophoictinia isura*		Vulnerable		Known
Turquoise parrot	*Neophema pulchella*		Vulnerable		Known

i. Status in NSW is available from the NSW Department of Environment and Conservation, 1 September 2005, http://threatenedspecies.environment.nsw.gov.au/tsprofile/browse_veg.aspx (search by habitats 'forested wetlands', 'freshwater wetlands').

ii. For EPBC-listed species, wetland dependency was determined using MDBA recommendations. For NSW-listed species this was determined from species information supplied from the NSW Department of Environment and Conservation, 1 September 2005 http://threatenedspecies.environment.nsw.gov.au.

iii. Cleland, ED (2008). Identifying habitat requirements for birds on cotton farms in the Lower Namoi. Cotton Catchment Communities Cooperative Research Centre, Narrabri.

iv. NSW Department of Environment and Conservation, 1 September 2005, http://www.threatenedspecies.environment.nsw.gov.au/tsprofile/profile_data.spx?id=10105&cma=Namoi

Table 15: Other species of significance in the Namoi catchment

Common name	Scientific name	EPBC Act listing	NSW status	Wetland Dependent[v]	Presence
Aquatic species					
River snail	*Notopala sublineata*		Endangered		Known
Purple spotted gudgeon	*Mogurnda adspersa*		Endangered		Known
Silver perch	*Bidyanus bidyanus*		Vulnerable		Known
Olive perchlet	*Ambassis agassizii*		Endangered		Known
Murray cod	*Maccullochella peelii peelii*	Vulnerable			Known
Freshwater catfish	*Tandanus tandanus*		Endangered		Known
Aquatic ecological community in the natural drainage system of the lowland catchment of the Darling River.	This community includes 21 native fish species and hundreds of native invertebrate species, many of which have not been comprehensively studied.		Endangered ecological community		Known
Non-aquatic species					
Booroolong frog	*Litoria booroolongensis*	Endangered	Endangered	Yes	Known (outside where entitlements are held).
The Bell's turtle	*Elseya belli*	Vulnerable	Vulnerable	Yes	Known (outside where the Commonwealth has entitlements).
Brush-tailed phascogale	*Phascogale tapoatafa*		Vulnerable	Often found around swamps.	Predicted
Davies tree frog	*Litoria daviesae*		Vulnerable	Yes	Known (outside where the Commonwealth has entitlements—Walcha Plateau).

Common name	Scientific name	EPBC Act listing	NSW status	Wetland Dependent[v]	Presence
Glandular frog	*Litoria subglandulosa*		Vulnerable	Yes	Known (outside where the Commonwealth has entitlements—Walcha Plateau).
Greater broad-nosed bat	*Scoteanax rueppellii*		Vulnerable	Forages along rivers.	Known
Five-clawed worm-skink	*Anomalopus mackayi*	Vulnerable	Endangered	No—inhabits damp places.	Known
Pale-headed snake	*Hoplocephalus bitorquatus*		Vulnerable	No—often found in streamside areas.	Known
Sloane's froglet	*Crinia sloanei*		Vulnerable	Yes	Known[vi]
Squirrel glider	*Petaurus norfolcensis*		Vulnerable	Unknown–utilises RRG forest as habitat.	Known
Stripe-faced dunnart	*Sminthopsis macroura*		Vulnerable	Unknown—often found along drainage lines.	Known

v. For EPBC-listed species, wetland dependency was determined using MDBA recommendations. For NSW-listed species this was determined from species information supplied by the NSW Department of Environment and Conservation, 1 September 2005, http://threatenedspecies.environment.nsw.gov.au.

vi. This has been confirmed by Namoi CMA officers through email correspondence with Ms S Eagan, 9 July 2009.

Appendix 3
Namoi Asset/WMA detailed information for watering orders

Unlike large wetland complexes, such as those found in the Gwydir, Macquarie and Lachlan catchments where duration and total flow volumes over weeks or months are important, the Namoi water-dependent ecosystems are largely driven by the daily (or even instantaneous) flows that link the benches, cutoff channels, anabranches and floodplains. The Namoi ecological assets are linked to reaches and are based on maintaining the processes for river health such as organic carbon transfer and nutrient cycling, as well as direct impact on vegetation condition and habitat availability.

The following information provides the source of the determination of the water orders in Table 11. The River Style analysis, which assessed around 10,000 kilometres of stream, found 23 different River Styles in the Namoi catchment (Lampert & Short 2004). These have been divided into four broad categories based on valley morphology including confined, partly-confined, laterally-unconfined and discontinuous. The determination of River Style and indicative condition of assessed streamlines in the Namoi catchment provided a geomorphic basis for prioritising river conservation and rehabilitation efforts (Lampert & Short 2004).

Other information sources are cited and additional analyses undertaken by consultants.

Asset—Split Rock Dam to Keepit Dam

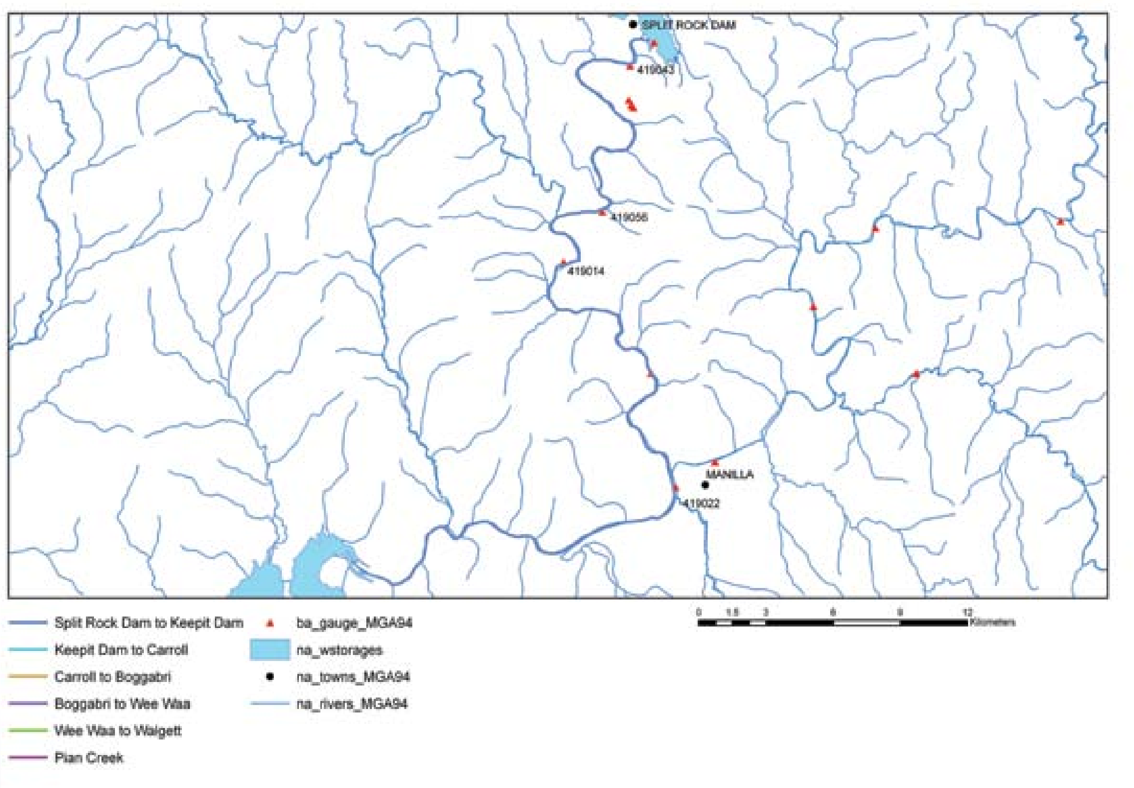

Figure 8: Location of Split Rock Dam to Keepit Dam reach (DIPNR (2004) Barwon Region shapefiles)

- Zone (Thoms 1998): mobile.
- River Styles (Lampert & Short 2004): partly confined, bedrock controlled, gravel.
- Length of main channel reach: 52.3 kilometres.

Summary description

The major water storages in the region include Keepit Dam on the Namoi River with a capacity of 425 gigalitres and the Split Rock Dam on the Manilla River, 28 kilometres from the township of Manilla, with a capacity of 397 gigalitres. Major irrigation development followed the completion of Keepit Dam on the Namoi River in 1961 and Split Rock Dam on the Manilla River in 1988. Split Rock Dam was designed to supply water for irrigation for licensees between Split Rock and Keepit Dam and to provide an augmentation supply to Keepit Dam during periods of drought. On the upper Namoi River, 9,724 megalitres of entitlement is located between Split Rock and Keepit Dams.

The Upper Namoi Regulated Water Source applies to the Manilla River downstream of Split Rock Dam and the Namoi River from the junction of the Manilla River downstream to Keepit Dam (Figure 8). Annual surface water use is strongly influenced by the seasonal rainfall patterns which cause inflows into the Keepit and Split Rock Dams and the access by irrigators to supplementary water during periods of high river flow. Surface water diversions in 2000 for the combined Namoi and Peel River systems were 315 gigalitres, including an estimated 42 gigalitres of use by unregulated stream licenses.

The Barwon Region Riverine Assessment Unit undertook macroinvertebrate sampling at a number of locations during the period leading up to the bulk water transfer trial between Split Rock and Keepit Dams. The same sites were sampled again during the trial release and further sampling was undertaken during the subsequent spring/summer period.

Of particular concern was the potential impact of high flows of extended duration and magnitude on platypus (*Ornithorynchus anatinus*) which are known to inhabit the area. During their breeding season (September–January) there is a potential for drowning either the eggs or hatchlings unable to escape burrows during periods of inundation from high flows. Although platypus are not generally considered an endangered species, there is a potential threat to their security at specific locations. The bulk water transfer trial and subsequent bulk transfer was initiated as soon as possible prior to the platypus breeding season to reduce the anticipated impacts on breeding pairs by 'forcing' them to adjust their brood burrows at a higher level in the riverbank thus reducing the possibility of drowning eggs or juvenile platypus during the high flow episode of the trial.

Foster (2001) provided draft guidelines for transferring water between Split Rock and Keepit Dams. The guidelines outlined transfer restrictions (i.e. river crossings, pumps and other infrastructure) as well as ecological restrictions (such as platypus requirements during breeding), and provided indicative volumes/hydrographs for bench wetting, streambed scouring and the prevention of streambank slumping.

Water Management Areas

- River channel
- River banks

Asset—Keepit Dam to Carroll

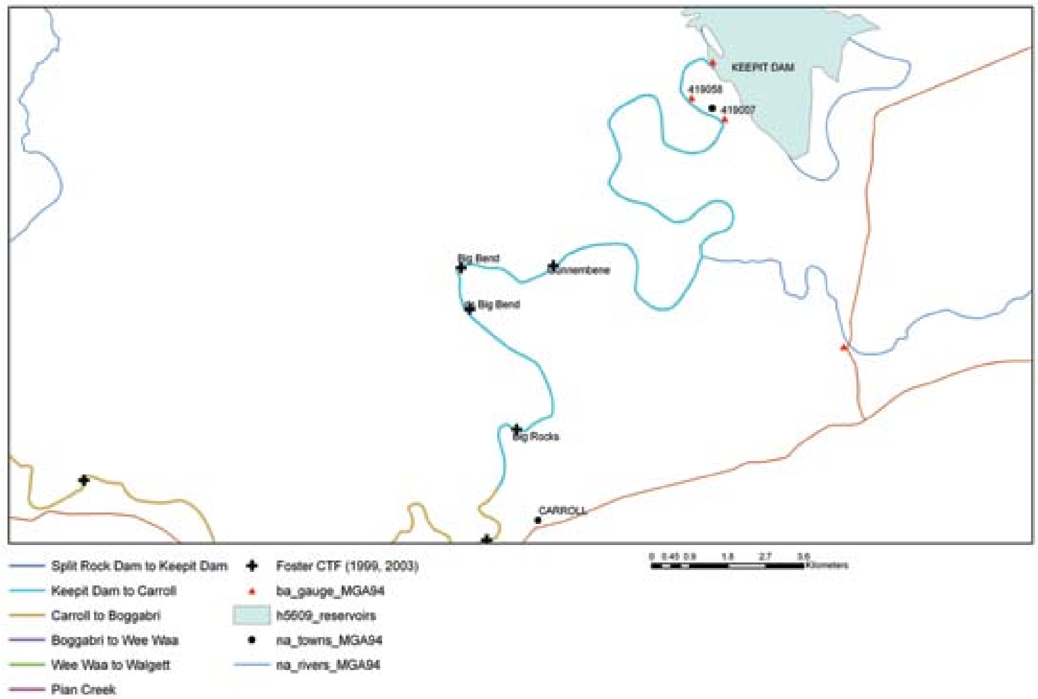

Figure 9: Location of Keepit Dam to Carroll reach (DIPNR (2004) Barwon Region shapefiles)

- Zone (Thoms 1998): mobile.
- River Styles (Lampert & Short 2004): partly confined, bedrock controlled, gravel.
- Condition (Lampert & Short 2004): moderate
- Length of main channel reach: 28.7 kilometres.

Summary description

Keepit Dam is situated approximately 60 kilometres west of Tamworth and 40 kilometres north-east of Gunnedah on the Namoi River (Figure 9). The catchment area for the dam is 41,350 square kilometres and it provides a reliable water source for downstream irrigators, industry and towns.

Keepit Dam has a capacity of 423,000 megalitres, a maximum depth of 40 metres, a mean depth of 9.6 metres and covers an area of 44 square kilometres (Preece 2004). Completed in 1960, the dam was built to regulate flow for irrigated crop production (principally cotton) in the Namoi River. Regulated discharges are made via a fixed level off-take structure positioned approximately 24 metres below full supply level (Preece 2004). The Keepit Dam Upgrade incorporates two measures to improve downstream environmental conditions—a multi-level off-take and a fishway.

The largest discharges from the dam coincide with peak irrigator demand and occur from December to February (Preece & Jones 2002, Boys et al. 2009). Median January discharge during the peak irrigation period is approximately 2,000 ML/d, and outside the irrigation period minimum flows approximate 10 ML/d. The current belief is that during the peak irrigation season a 5 °C depression in river temperature occurs 2 kilometres downstream of Keepit Dam, with the impact being largely eliminated by 40 kilometres downstream (Preece & Jones 2002).

Temperature suppression downstream of Keepit Dam is observed from September to March and the largest differences between upstream and downstream temperatures are observed between October and January (Preece & Jones 2002). The maximum annual temperature immediately downstream of Keepit Dam occurs in February, which is several weeks later than expected naturally (Preece & Jones 2002).

Table 16 indicates possible commence-to-flow values for in-stream and floodplain features between Keepit Dam and Gunnedah.

Table 16: Commence-to-flows (Q) for Keepit Dam to Gunnedah (Keepit Dam to Carroll reach)

Site no.	Site	Description	Height (m)	Estimated Q (ML/d) at Gunnedah Gauge (419001)
1	Gunnembene Crossing	Bench	2.3	8,000–9,000
		Bench	1.3	3,000–4,000
		Point Bar	1.7	5,000–7,000
2	Big Bend	Bench	5.1	20,000–25,000
		Point Bar	2.0	7,000–8,000
3	D/S Big Bend	Bench	1.9	5,000–6,000
		Billabong	3.5	14,000–16,000
4	Phantom Rock	Point Bar/Bench	1.1	2,000–4,000
		Backwater	3.5	15,000–17,000

Source: Foster 2003.

Note: No hydraulic analysis has been undertaken and the commence-to-flow values are only estimates based on flows at Gunnedah Gauge (419001).

Asset—Carroll to Boggabri

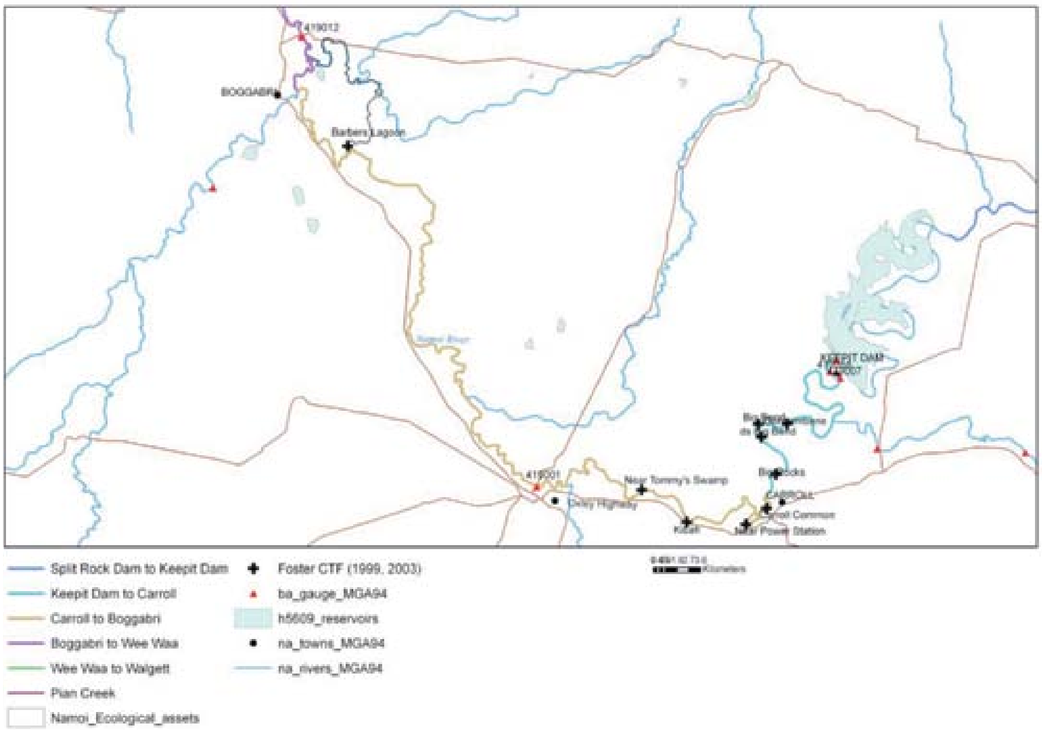

Figure 10: Location of Carroll to Boggabri reach (DIPNR (2004) Barwon Region shapefiles)

- Zone (Thoms 1998): meander.
- River Styles (Lampert and Short 2004): laterally unconfined, low sinuosity, gravel.
- Condition (Lampert and Short 2004): moderate.
- Length of main channel reach: 89.1 kilometres.

Summary description

This asset section commences at the village of Carroll, downstream of the confluence of the Peel and Namoi Rivers, and extends north and west, past Gunnedah, to the town of Boggabri (Figure 10). The Namoi River between Keepit Dam and Boggabri and the catchments of Mooki River and Coxs Creek form the region known as the Liverpool Plains. The Namoi River has a catchment area at the village of Carroll of 10,500 square kilometres and 17,000 square kilometres at the town of Gunnedah (Webb, Mckeown & Associates 2006).

Gulligal Lagoon, located in this reach, fills as a result of flooding and the extensive catchment areas of ephemeral streams, with Collygra Creek and Deadman's Gully as important contributors. Gulligal Lagoon has been known to fill when the Namoi River at Gunnedah is at 5 metres, a height at which most of the river does not break its banks.

Possible commence-to-flow values for features between Carroll and Gunnedah is indicted in the table below.

Table 17: Commence-to-flows (Q) for Carroll to Gunnedah (Carroll to Gunnedah reach)

Site no.	Site	Description	Height (m)	Estimated Q (ML/d) at Gunnedah Gauge (419001)
5	Carroll Common	Bench	2.1	7,000–8,000
		Bench	3.5	15,000–17,000
		Bench	5.0	23,000–25,000
6	Near power substation	Floodrunner	1.8	5,000–7,000
7	Near Tommy's Swamp	Backwater/anabranch	2.1	7,000–8,000
8	Kibah	Anabranch	7.2	40,000
		Abandoned channel	6.0	28,000–30,000

Source: Foster 2003.

Note: No hydraulic analysis has been undertaken and the commence-to-flow values are only estimates based on flows at Gunnedah Gauge (419001).

Asset—Boggabri to Wee Waa

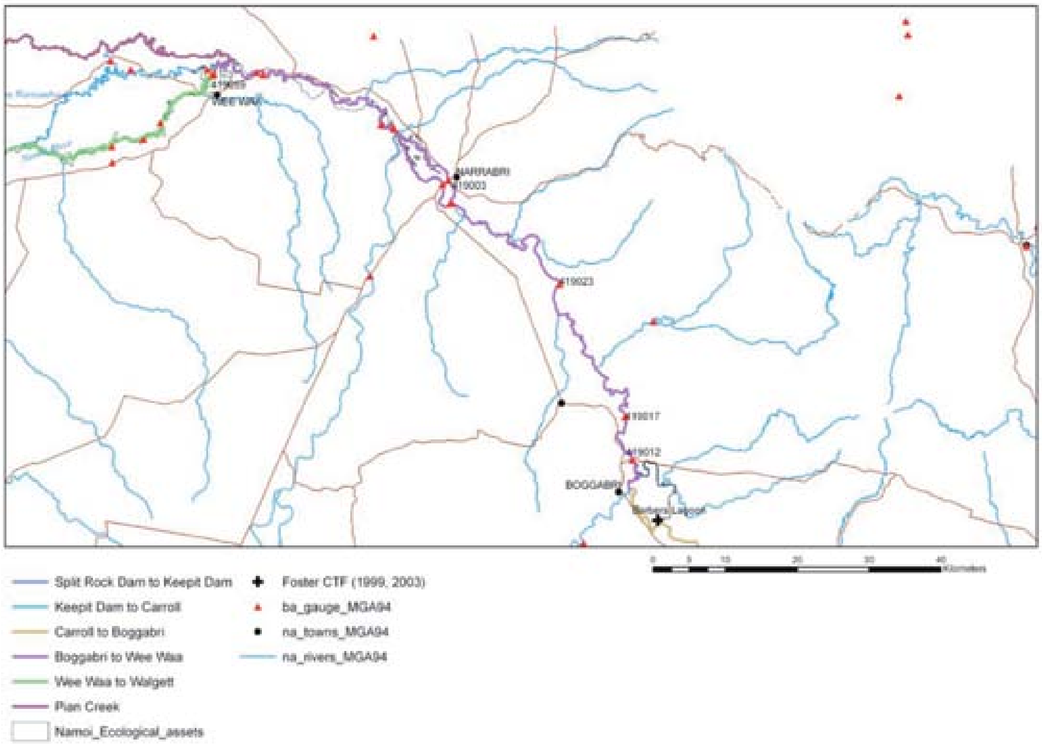

Figure 11: Location of Boggabri to Wee Waa reach (DIPNR (2004) Barwon Region shapefiles)

- Zone (Thoms 1998): anabranch.
- River Styles (Lampert and Short 2004): laterally unconfined, low sinuosity, gravel (Boggabri to u/s Pian Creek off-take).
- Condition (Lampert and Short 2004): moderate.
- Length of main channel reach: 140.6 kilometres.

Summary description

Major tributaries to the Namoi are located upstream of Boggabri (Figure 11). The reach between Boggabri and Narrabri is characterised by long, narrow lagoons that are prior channels of the Namoi River (Green et al. 2011). This includes Barbers Lagoon, a major anabranch within that reach. Downstream of Narrabri, the carrying capacity of the Namoi River is significantly reduced, and subsequently, floodwaters spread out through an effluent system over a vast floodplain. This area is considered the start of the true riverine zone of the Namoi catchment due to the increased frequency of lagoons, the low gradient of the channel and the development of anabranches and effluent channels. There are large numbers of lagoons in this reach, although most are small and require overbank flooding for inundation (Green & Dunkerley 1992). Two major weirs, Mollee and Gunidgera, are located downstream of Narrabri and are used to regulate water for irrigation, stock and domestic users in the lower Namoi (Green et al. 2011).

A significant feature of the river system at Narrabri is Narrabri Creek. This creek is a modified anabranch of the Namoi River which now takes a large proportion of the flow. Narrabri Creek starts just upstream of Narrabri and rejoins with the Namoi River downstream of the town, travelling 5–8 kilometres. The Narrabri Creek channel is highly degraded and actively widening through bank erosion and river bed aggradation. A remnant Namoi River channel remains and will flow when the Namoi River exceeds 25,000 to 30,000 ML/d.

Twelve native fish species, including the threatened silver perch and endangered populations of olive perchlet and purple-spotted gudgeon are known and expected to inhabit this asset reach. The inundated floodplain provides a nursery habitat for these fish, particularly golden and silver perch, that spawn in response to flooding. These species have a migratory response to flooding and spawn their eggs on or near the floodplain where larvae can readily access flood sources.

The Namoi demonstration reach is located between Narrabri and Boggabri and forms part of the Namoi Aquatic Habitat Initiative. This collaborative project between the Namoi Catchment Management Authority (CMA), Murray-Darling Basin Authority (MDBA), NSW Fisheries and land owners focuses on restoration activities including revegetation, fencing, erosion control, de-stocking and removal of fish barriers.

The demonstration reach highlights habitat restoration techniques and encourages native fish back into the waterways. Actions include remediating or removing priority barriers so that fish can move freely along the waterways, planting local native vegetation on stream banks, introducing large woody debris (snags) into the water and managing environmental flows to suit native fish.

Water Management Areas

a) Barbers Lagoon (Figure 12 and Plate 1)

b) Namoi River and Anabranches u/s Mollee Weir

c) Namoi River Red Gum corridor Mollee Weir to Gunidgera Weir (Wee Waa)

a) Barbers Lagoon

Figure 12: Satellite image of Barbers Lagoon 27/1/2004 (NASA Landsat Program, Landsat TM, Level 1 GeoTIFF, LT50910812004027, downloaded from www.glovis.usgs.org 30 June 2011. Displayed as MGA94, Enhanced True colour). Lagoon shown in red.

Plate 1: Barbers Lagoon (photo courtesy of NOW, undated)

Barbers Lagoon (shown above in Plate 1 and in red on the satellite image in Figure 12) is a 22-kilometre anabranch of the Namoi River located near Boggabri covering an area of approximately 134 hectares.

The lagoon also has inflow tributaries so may receive runoff water from local rainfall as well as from Namoi River flows. At the downstream end, adjacent to a road reserve, is the deepest pools in the lagoon, which was also monitored as an IMEF site by the former DLWC from 2000–2004. There is a mix of intact riparian vegetation and areas that have been cleared and cultivated. The estimated commence-to-flow (from Namoi River @ 419012) is 4,600 ML/d based on the information below (Table 18).

Table 18: Commence-to-flows for Boggabri to Wee Waa (Barbers Lagoon)

Date	Flow at 419021 (ML/d)	Remote sensing analysis*	IMEF water depth max (m)
15/3/2001	8,200	Possible isolated pools	1.2
13/01/2002	3,250	Possible isolated pools	1.2
01/02/2003	Dry	Dry	0
06/04/2003	4,000	1km pool	No data
27/01/2004 (Figure 12)	7,600	8km wet d/s end	1.5
Commence-to-flow upstream of off-take (Foster 1999)	4,602 @ 419012		

Source: Foster 2003.

* Total length is 22 kilometres.

b) Namoi River and anabranches upstream Mollee Weir

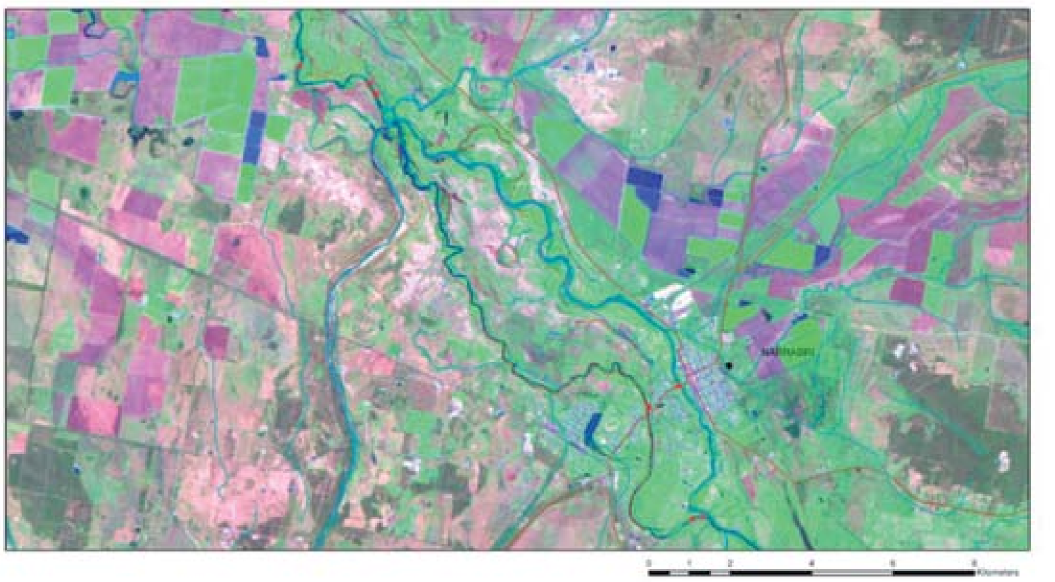

Figure 13: Satellite image of Namoi Anabranches upstream of Mollee Weir (NASA Landsat Program, Landsat TM, Level 1 GeoTIFF, LT50910812004027, downloaded from www.glovis.usgs.org 30 June 2011. Displayed as MGA94, Enhanced True colour).

- Total area: 930 hectares.
- Values: anabranch, riparian corridor, cutoff channels, floodplain.

Summary description

The Namoi River splits into the Namoi River and Narrabri Creek upstream of Narrabri (Figure 13). Most low flows pass through Narrabri Creek with Namoi River flowing at higher flows only. Mollee Weir, located downstream of Narrabri, backs up water into a weir pool along both Narrabri Creek and the Namoi River. Between the two watercourses lie some floodplain features that inundate at moderate-to-high flows. This 'asset' includes the riparian channel and some floodplain wetlands covering a total area of approximately 930 hectares. Predominant land uses for this area is urban and grazing. The ecological value of this reach appears to be limited.

The gauges at Narrabri Creek (419003) and Namoi River (419002) are shown above as red triangles within Narrabri township (Figure 13). Comparison of the two gauges over the same time period (1990–1995) of low flows suggests a commence-to-flow for Namoi River in the order of 1,250 ML/d, however, there is a large degree of uncertainty due to backwater effects from Mollee Weir. The low-flow events between 1993 and 1995 suggest a commence-to-flow of between 1,500 ML/d (peaking in February 1994 in Narrabri Creek which did not result in flow in Namoi River) and 1,650 ML/d (peaking in August 1993). Remote sensing analyses suggest that the commence-to-flow for floodplain features is greater than the highest flow assessed of 8,200 ML/d, although local rainfall may fill some features (Figure 14).

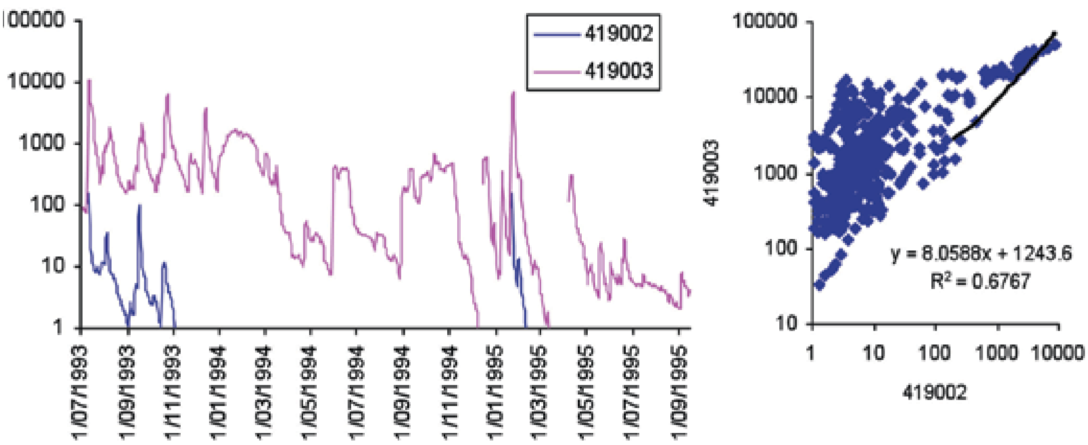

Figure 14: Analysis of flow rates (ML/d) at Namoi River and Narrabri Creek at Narrabri

Estimated commence-to-flow (measured at 419002): 1,600 ML/d (channel), greater than 8,200 ML/d (floodplain features).

c) Namoi River Red Gum Corridor, Mollee Weir to Gunidgera Weir

Figure 15: Satellite image of Namoi River from Mollee Weir to Gunidgera Weir 27/1/2004 (NASA Landsat Program, Landsat TM, Level 1 GeoTIFF, LT50910812004027, downloaded from www.glovis.usgs.org 30 June 2011. Displayed as MGA94, Enhanced True colour).

- Total area: 3,194 hectares.
- Length of main channel reach: 40 kilometres.
- Values: main channel, riparian corridor, cutoff channels, floodplain.

Summary description

This reach contains relatively small lagoons, with most requiring overbank flooding for inundation (Figure 15). While some appear to be in a natural state, others contain groups of dead trees indicating their probable use as water storages (DIPNR 2003). Lagoons include:

- Reedy Lagoon—a narrow lagoon with a fringe of river red gums. Several shallow depressions nearby which are largely cultivated.
- Gurleigh Lagoon and Sheep Station Creek—forms a short anabranch of the river. The lagoon is connected to the creek and both are deep narrow channels dominated by river red gum. The creek has been dammed at either end since 1972 in order to retain stock and irrigation water. Minor floods are required to fill the creek and lagoon.
- Wirebrush Lagoon—the largest wetland in the area, characterised as a broad shallow depression. The lagoon is semi-permanent and is considered to possess significant habitat value due to the surrounding vegetation of coolibah and river cooba with occasional river red gum. It receives water from the river during high surplus flows via the Myall Vale Channel.
- Wee Waa Lagoon—a long, narrow lagoon located on the eastern side of Wee Waa. It is subject to flooding from the Namoi system, as well as from local flows from the Pilliga Scrub area. The Wee Waa levee abuts the lagoon.
- Possible commence-to-flow values for features in this reach are indicated in the table below.

Table 19: Commence-to-flows for Boggabri to Wee Waa (Mollee to Gunidgera Weirs)

Date of imagery	Flow (419039) peak prior to imagery (ML/d)	Remote sensing analysis (anabranches and billabong features)
15/3/2001	11,237	Partially wet with water in anabranches and some features.
13/01/2002	3,546	Partially wet in anabranch, most features dry.
01/02/2003	2,973	Most features dry, possibly some water in anabranch.
06/04/2003	3,958	Most features dry, possibly some water in anabranch.
27/01/2004 (Figure 15)	19,108	Many features wet (as per above image).

Source: Foster 2003.

Note: The large anabranch and wet area in the middle of the image above may be used as water storage or water diversions.

Asset—Wee Waa to Walgett

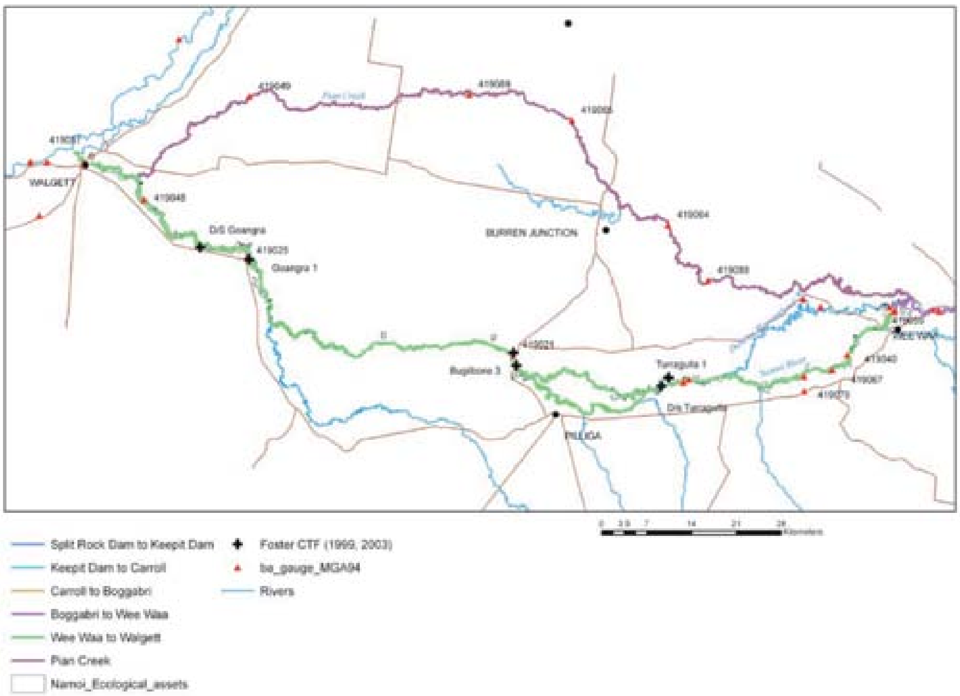

Figure 16: Location of Wee Waa to Walgett reach (DIPNR 2004, Barwon Region shapefiles)

- Zone (Thoms 1998): distributary.
- River Styles (Lampert & Short 2004): laterally unconfined, anabranching, meandering fine grained.
- Condition (Lampert & Short 2004): moderate.
- Length of main channel reach: 280.7 kilometres.

Summary description

Downstream of Wee Waa, the Namoi River progresses into the distributary zone where development of many anabranches and flood runners occur (Figure 16). Small tributary creeks draining the Pilliga Scrub to the south often contribute large volumes of water to the Namoi River and its adjacent floodplain wetlands. Near the town of Pilliga, the Namoi River splits into two channels for a distance of 6 kilometres. Duncans Warrambool, the northern channel, carries two-thirds of the flow. This section of the Namoi River contains small areas of intact remnant riverine and wetland ecosystems. Between the Namoi River to the south and Pian Creek to the north are a number of ephemeral watercourses that flow westward across the floodplain. They include Drildool, Cubbaroo, Dead Bullock and Chambers Warrambools and Coolibah Watercourse. This area is characterised by very flat terrain with elevations dropping approximately 1 metre per 1,500 metres (0.067 per cent) generally in an east-to-west direction. Small variations in contours are associated with drainage lines and alluvial depositions along stream courses.

Following the construction of Keepit Dam in 1960 and the introduction of cotton, the Namoi River Valley experienced a major shift in agriculture from low-intensity to high-intensity land use. The area of irrigated cotton in the valley expanded from 25 hectares in 1961 to approximately 30,000 hectares in 1984. The majority of landholders in the Narrabri–Wee Waa system now practice cropping, with the dominant system being cotton and cereal crop rotation. Some grazing still occurs but is gradually becoming less common.

The natural vegetation on the floodplains has been cleared to make way for cultivation. Several significant areas of vegetation mapped in 1985 had obviously been cleared. Nonetheless, this mapping indicates that vegetation within the area is typified by the following vegetation communities. River red gum forests are associated with major rivers and clay plains along streamlines and ox-bows. Coolibah is often dominant along minor streamlines. Significant vegetation communities located in this area include:

- Coolibah/poplar box woodlands—the remnant type typically occurs north of Wee Waa on the interzone between the black soil dominated alluvial plains and the more elevated earthy soils dominating the peneplain. It comprises elements of both coolibah and poplar box in a complex mosaic.
- Open coolibah woodlands with degraded understorey located on flats and banks on alluvial plains.
- Coolibah/river red gum woodland—associated with broad floodplain areas and often containing shallow depressions and streamlines. These remnants are typified by coolibah woodlands with a herbaceous understorey.
- Brigalow shrubland—typified by the dominance of brigalow, this remnant type also contains pockets dominated by belah and poplar box and is usually found on flats. The upper stratum species dominance seems to relate to site-drainage characteristics, the belah favouring the poorer-drained sites and the poplar box favouring the better-drained sites.

Water Management Areas

a) Namoi River Red Gum Corridor Gunidgera Weir to Weeta Weir

b) Duncans Warrambool (Turragulla)

c) Namoi River Red Gum Corridor downstream Duncans Junction to Bugilbone

d) Namoi River Red Gum/Coolibah Corridor Bugilbone to Goangra

e) Namoi River Red Gum/Coolibah Corridor downstream Goangra.

a) Namoi Billabongs, Gunidgera Weir to Weeta Weir

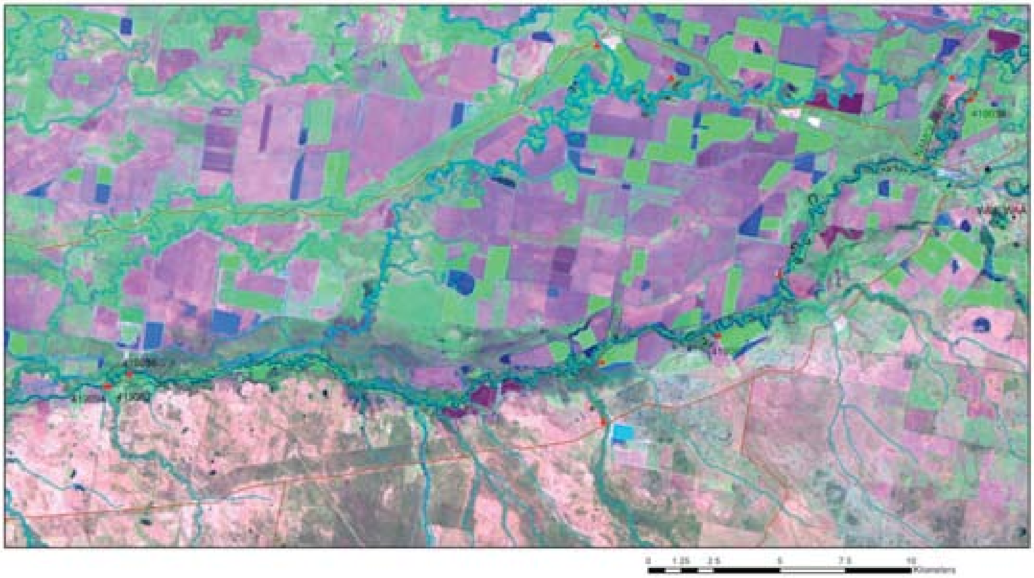

Figure 17: Satellite image of Gunidgera Weir to Weeta Weir 27/1/2004 (NASA Landsat Program, Landsat TM, Level 1 GeoTIFF, LT50910812004027, downloaded from www.glovis.usgs.org 30 June 2011. Displayed as MGA94, Enhanced True colour).

- Zone (Thoms 1998): distributary.
- River Styles (Lampert & Short 2004): anabranching, meandering fine grained.
- Condition (Lampert & Short 2004): moderate.
- Total area: 2003 hectares.
- Length of main channel reach: 45 kilometres.
- Values: main channel, riparian corridor, cutoff channels/billabongs, floodplain.

Summary description

The Namoi River between Gunidgera and Weeta Weirs is an area of floodplain that has been extensively cleared with few wetland areas identified (Figure 17). A few small u-shaped lagoons within the riverine zone offer the only natural wetland habitat in this section of the river.

Gunidgera Creek has extensive floodplain development and, as such, the only natural wetland areas available have been hydrologically modified in some way.

1. Cudgewa Storage and Lagoon is located in the channel of a floodway that previously flowed between Gunidgera Creek and Pian Creek. The storage is leveed on all sides and water is pumped into the storage from Gunidgera Creek. Many dead trees occur within the storage along the line of the original water level. The lagoon is a part of the old watercourse downstream of the storage and becomes inundated during flood events.
2. Woodlands Billabong is part of a u-shaped lagoon that has been cut in half by a leveed irrigation channel. Surplus flows are pumped into the storage from Gunidgera Creek and floodwaters may also flow over the levee and into the storage. The vegetative fringe of the storage consists mainly of river red gum. Water is stored for stock and wildlife.

3. "Weeta Waa" Lagoon is a large meander of Gunidgera Creek that has been cut off from the rest of the creek by dams at either end. The dominant vegetation is cumbungi, with coolibah, river cooba and lignum. The water stored is primarily used for irrigation.

Possible commence-to-flow values for features associated with this reach are indicated in the table located below.

Table 20: Commence-to-flows for Gunidgera Weir to Weeta Weir

Date of imagery	Flow (419021) peak prior to imagery (ML/d)	Remote sensing analysis (Billabongs)	Approx. surface area wet (Billabongs) (Ha)
15/3/2001	8,200	Some wet	10
13/01/2002	3,250	Dry	0
01/02/2003	Dry	Dry	0
06/04/2003	4,000	Dry	0
27/01/2004 (Figure 17)	7,600	Mostly wet	17

Source: Foster 2003.

b) Duncans Warrambool (Turragulla)

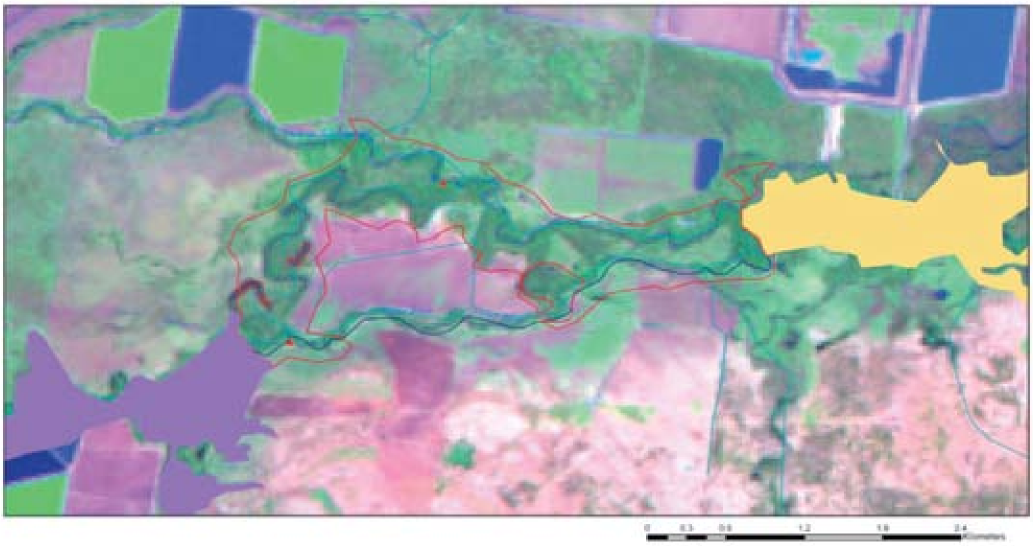

Figure 18: Satellite image for Duncans Warrambool 27/1/2004 (NASA Landsat Program, Landsat TM, Level 1 GeoTIFF, LT50910812004027, downloaded from www.glovis.usgs.org 30 June 2011. Displayed as MGA94, Enhanced True colour).

- Zone (Thoms 1998): distributary.
- River Styles (Lampert & Short 2004): anabranching, meandering fine grained.
- Condition (Lampert & Short, 2004): moderate.
- Total area: 300 hectares.
- Values: anabranch, riparian corridor, cutoff channels/billabongs, floodplain.

Summary description

The Namoi River splits into two channels near Pilliga for a distance of 6 kilometres. The northern channel, known as Duncans Warrambool, carries two-thirds of the flow (Figure 18).

Table 21: Commence-to-flows for Duncans Warrambool

Date of imagery	Flow (419021 and 419095) peak prior to imagery (ML/d)	Remote sensing analysis (anabranch)
15/3/2001	8,200–20,420	Wet
13/01/2002	3,250	Dry
01/02/2003	Dry–600	No data (cloud)
06/04/2003	4,000–3,936	Dry
27/01/2004 (Figure 18)	7,600–18,817	Wet
Commence-to-flow analysis	**Foster (1999)**	
Anabranch (u/s)	3,230@419082	
Bench	1,740@419082	
Anabranch (d/s)	3,300@419082	

Note: 419082 (Namoi River u/s Duncans Junction) was moved to 419095 (Namoi @ Bullawa) around 2000. No data available for 419082, approximate flows for remote sensing analysis were taken from 419095.

Remote sensing analysis could not confirm the commence-to-flow as indicated by Foster (1999) but does indicate that commence-to-flow is greater than 3,940 ML/d at 419095.

It is suggested that 4,000 ML/d should be used as the commence-to-flow for this anabranch as an interim measure, but this requires confirmation.

c) Namoi River Red Gum Corridor downstream Duncans Junction to Bugilbone

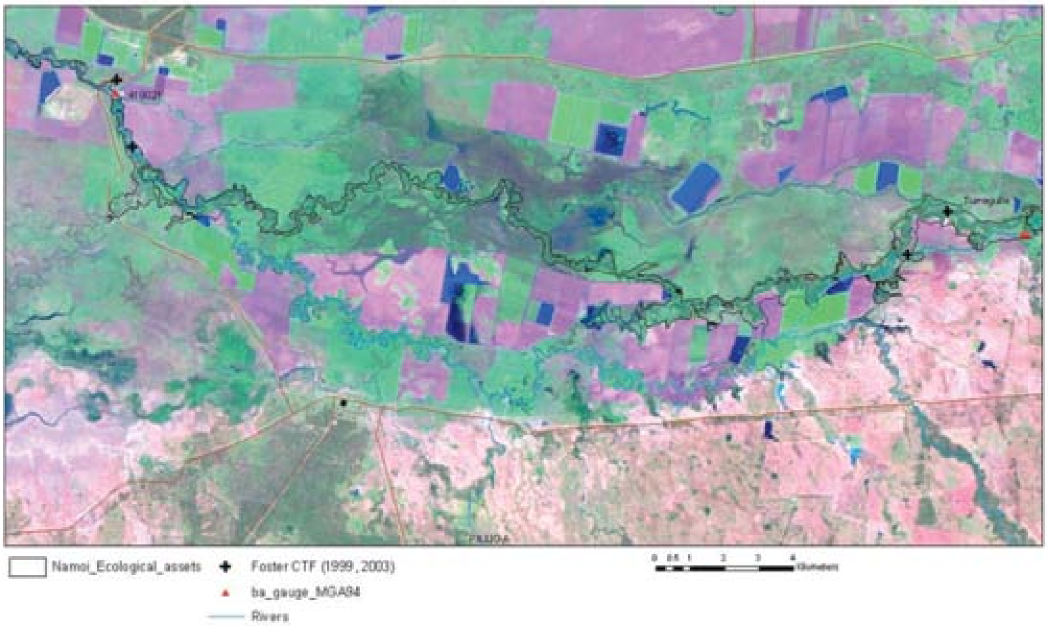

Figure 19: Satellite image for Duncans Junction to Bugilbone 27/1/2004 (NASA Landsat Program, Landsat TM, Level 1 GeoTIFF, LT50910812004027, downloaded from www.glovis.usgs.org 30 June 2011. Displayed as MGA94, Enhanced True colour).

Plate 2: Duncan's Junction (photo courtesy of NOW, undated)

- Zone (Thoms 1998): distributary.
- River Styles (Lampert & Short 2004): anabranching, meandering fine grained.
- Condition (Lampert & Short 2004): moderate.
- Total area: 1,122 hectares.
- Values: anabranch, riparian corridor, cutoff channels/billabongs, floodplain.

Summary description

The main vegetation community in this area is the endangered coolabah—black box woodlands which are found throughout the sub-catchment. Other areas are dominated by Myall woodlands and bimble box—belah woodlands, with many wetlands and billabongs found along the river.

Land use is predominantly dryland farming and grazing due to a lower rainfall. Irrigated farming and cotton production are also practised in this area but only on a small scale. The issues within this area are invasive vegetation regrowth, dryland salinity, pasture degradation and riparian management (NCMA 2009).

Duncan's Junction is located in an abandoned channel of the Namoi River approximately 20 kilometres upstream of Pilliga (Figure 19; Plate 2). This wetland is filled from the Namoi River via the downstream end. This allows the wetland to fill slowly, minimising the impact of high-velocity scouring flows which affect some of the other wetland sites. Water is held in deeper pools for long periods, resulting in azolla *(Azolla filiculoides*) and slender knotweed (*Persicaria decipiens*) dominating the water habitat. Cane grass (*Eragrostis australasila*) is also common in areas with high soil moisture, while Warrego summer grass (*Paspalidium juibiflorum*) dominates the drier areas. River cooba *(Acacia stenophylla)* and river red gums dominate the overstorey (IMEF information, NOW).

Plate 3: Namoi River (Wetland) upstream Bugilbone (source: NOW, undated).

Wetlands in this section are frequently dominated by *Cynodon dactylon* (couch grass), the most dominant grass species along with *Paspalidium juibiflorum* (Warrego summer grass). *Paspalum distichum* (water couch) is the principal aquatic species, inhabiting the edge of pools when they were filled by floodwater (IMEF information, NOW) (Plate 3). Table 22 shows commence-to-flow values for this reach.

Table 22: Commence-to-flows for Duncan's Junction to Bugilbone

Date of imagery	Flow (419021) peak prior to imagery (ML/d)	Remote sensing analysis (anabranch)
15/3/2001	8,200	No features discernable at landsat resolution (30 m).
13/01/2002	3,250	
01/02/2003	Dry	
06/04/2003	4,000	
27/01/2004 (Figure 19)	7,600	
Commence-to-flow analysis	**Foster (1999)**	
Anabranch	4,496@419021	
Bench 1	3,921@419021	
Bench 2	1,780@419021	
Bench 3	3,724@419021	

Foster (1999) commence-to-flow estimates:

- Low-level bench 1,800 ML/d @ 419021
- Mod-level bench 4,000 ML/d @ 419021
- Anabranches 4,500 ML/d @ 419021

d) Namoi River Red Gum/Coolibah Corridor Bugilbone to Goangra

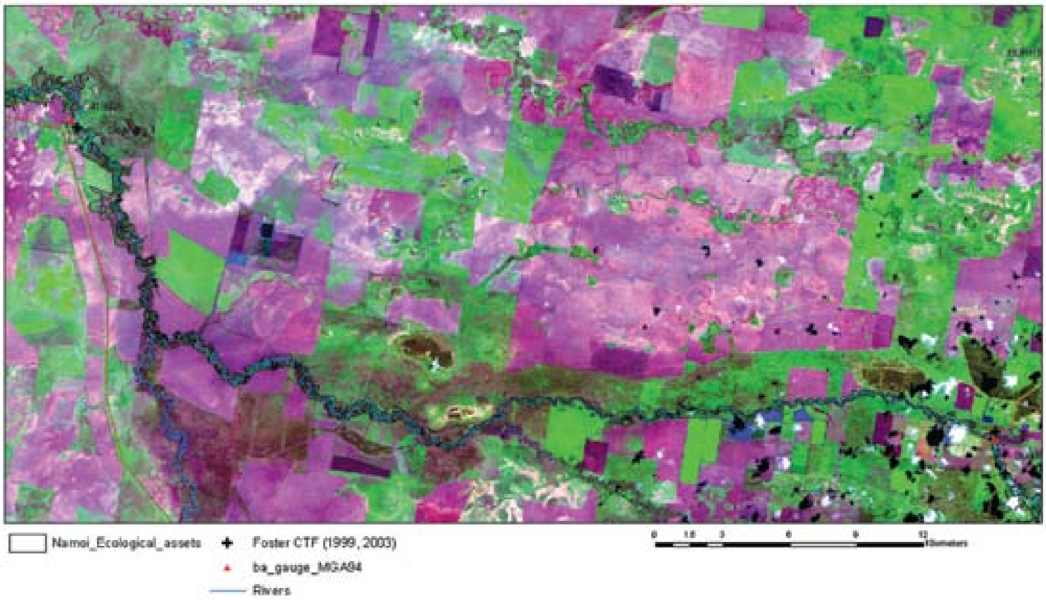

Figure 20: Satellite image of Bugilbone to Goangra 27/1/2004 (NASA Landsat Program, Landsat TM, Level 1 GeoTIFF, LT50910812004027, downloaded from www.glovis.usgs.org 30 June 2011. Displayed as MGA94, Enhanced True colour).

Plate 4: Namoi River (Wetland) upstream Goangra (source: NOW, undated)

- Zone (Thoms 1998): distributary.
- River Styles (Lampert & Short 2004): anabranching, meandering fine grained.
- Condition (Lampert & Short 2004): moderate.
- Total area: 1,690 hectares.
- Values: anabranch, riparian corridor, cutoff channels/billabongs, floodplain.

Summary description

Figure 20 and Plate 4 illustrate features of this reach. Minor increases in flow can result in wetland sites in this reach being inundated, filling the large pool in the middle of the wetland. Riparian vegetation often consists of river red gum though vegetation can be sparse in this area. Lesser joyweed (*Alternanthera denticulata*) and Warrego summer grass are often the most common plants (IMEF information, NOW).

Table 23: Commence-to-flows for Bugilbone to Goangra reach

Date of imagery	Flow (419021) peak prior to imagery (ML/d)	Remote sensing analysis (anabranch)
15/3/2001	8,200	No features discernable at landsat resolution (30 m).
13/01/2002	3,250	
01/02/2003	Dry	
06/04/2003	4,000	
27/01/2004 (Figure 20)	7,600	
Commence-to-flow analysis	**Foster (1999)**	
Low-flow bench	1,865@419026	
Moderate-flow bench	6,277@419026	
High-flow bench	13,766@419026	

e) Namoi River Red Gum/Coolibah Corridor d/s Goangra

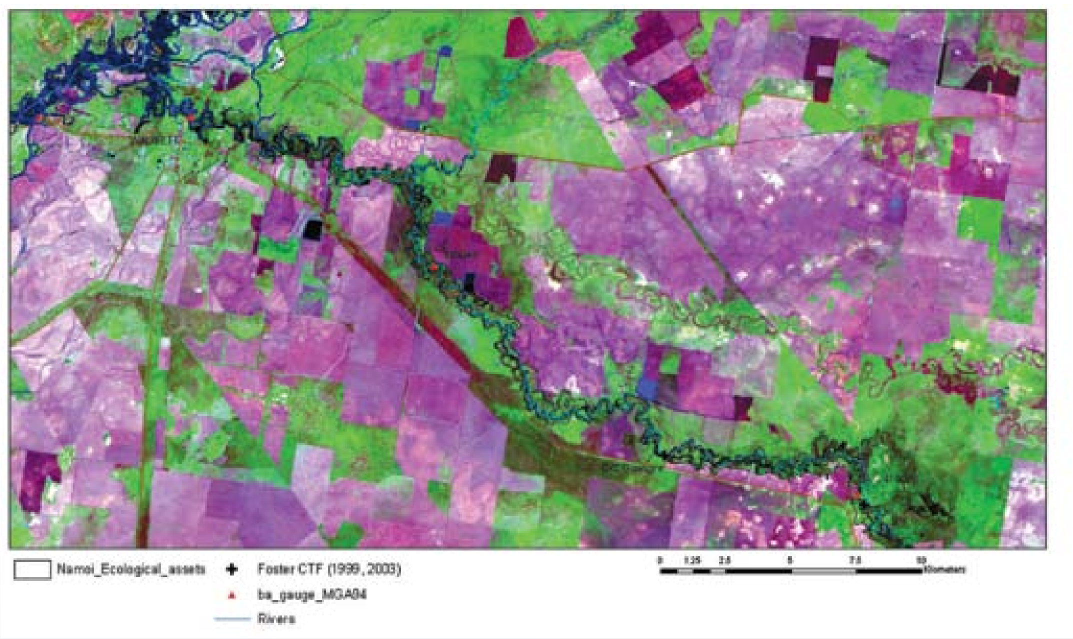

Figure 21: Satellite image downstream of Goangra 27/1/2004 (NASA Landsat Program, Landsat TM, Level 1 GeoTIFF, LT50910812004027, downloaded from www.glovis.usgs.org 30 June 2011. Displayed as MGA94, Enhanced True colour).

- Zone (Thoms 1998): distributary.

- River Styles (Lampert & Short 2004): anabranching, meandering fine grained.
- Condition (Lampert & Short 2004): moderate.
- Total area: 1,880 hectares.
- Values: anabranch, riparian corridor, cutoff channels/billabongs, floodplain.

Figure 21 illustrates features of the area downstream of Goangra. Table 23 shows likely commence-to-flow values for this reach.

Table 24: Commence-to-flows downstream Goangra

Date of imagery	Flow (419021) peak prior to imagery (ML/d)	Remote sensing analysis (anabranch)
15/3/2001	8,200	No features discernable at landsat resolution (30 m).
13/01/2002	3,250	
01/02/2003	Dry	
06/04/2003	4,000	
27/01/2004 (Figure 21)	**7,600**	
Commence-to-flow analysis	Foster (1999)	
Low flow bench	2,148@419026	

Asset—Pian Creek

(See Figure 16)

- Zone (Thoms 1998): distributary.
- River Styles (Lampert and Short 2004): anabranching, meandering fine grained.
- Condition (Lampert & Short 2004): moderate.
- Length of main channel reach: 222.0 kilometres.

Summary description

In the vicinity of Wee Waa, floodwater leaves the Namoi River via a series of anabranches, with two being Pian Creek and Gunidgera Creek. These creeks are both used to distribute regulated irrigation supplies to properties along their reaches. During major flood events all of the country west of Wee Waa is inundated, with the exception of high ridges adjacent to and north of Pian Creek. Pian Creek continues flowing westwards until it rejoins the Namoi River upstream of Walgett, while Gunidgera Creek rejoins the river approximately 25 kilometres downstream of the off-take. Pian Creek has only a few discrete wetlands due to extensive floodplain development and the loss of a number of natural wetlands due to cultivation in this area. The main wetlands include:

1. Krui Swamp—a shallow depression surrounded by coolibah woodland. The main source of water is local drainage, filling only after intense rain.

2. Wilgamere—a very shallow lagoon and floodway. Water spills out of Pian Creek to the west of Merah North, flows along a shallow floodway and ponds in the floodway at "Wilgamere" forming a shallow lagoon. The lagoon would dry relatively quickly after flooding.

State Water provides two replenishment flow events, up to a combined total volume of 14,000 megalitres in a water year, to Pian Creek. These flows are to provide a visible flow for five or more consecutive days at Waminda gauge (419049). One replenishment flow must be delivered in the first half of the water year and the other in the second half of the water year, at intervals of no more than seven months apart under most circumstances. Releases to Pian Creek downstream from the Gunidgera off-take should meet the following conditions:

a) daily supply volumes in Pian Creek do not exceed 1,600 ML/d for no more than 10 per cent of days in any month in a water year; and

b) the maximum daily supply volume in Pian Creek does not exceed 2,000 ML/d.

Asset—Peel River

Summary Description

"The Peel River, directly downstream of Chaffey Dam, is a confined channel that is narrowing and becoming invaded by riparian vegetation due to the lack of high velocity flows. The lack of high velocity flows has also resulted in in-stream gravel becoming immobile and encrusted with filamentous algal mats and biofilms during summer.

Riverine vegetation supported by the Peel River includes emergent aquatic plants and river oaks, rough-barked apple and river red gum. Straw-necked ibis are often observed on floodplain areas in this zone.

A more natural flow regime which includes variability, frequency and magnitude downstream of Chaffey Dam is likely to improve in-stream foodwebs and physical channel habitats. This could be achieved by better management of regulated irrigation release or by the application of a stimulus flow rule. However, due to the outlet capacity restrictions of the dam, high velocity and increased volumes are difficult to achieve. Rules such as dam translucency and/or transparency may achieve some benefit without compromising irrigator reliability" (Foster (2003); Foster and Lewis (2009)).

Table 25 indicates possible requirements for features in the Peel River.

Table 25: Indicative commence-to-fill requirements of in-stream benches and distributary effluents of the Regulated Peel River

Site	Description	Estimated discharge required to wet benches (ML/d)	Relevant gauge
D/S Chaffey 1	In-stream benches	450 650 3,960 5,580	D/S Chaffey 419045
D/S Chaffey 2	In-stream benches	1,913 7,943 11,207	D/S Chaffey 419045
Woolomin	In-stream benches	240 550 2,280	D/S Chaffey 419045
D/S Woolomin	In-stream benches	500 420 700	D/S Chaffey 419045
D/S Dungowan	In-stream benches	320 730 1,412	Piallamore 419015
Peel River upstream of Cockburn River	In-stream benches	85 740 890 2,390 2,350 10,000	Piallamore 419015
Appleby Gauge	In-stream benches Floodrunner	600 7,300 9,000 10,275	Appleby Crossing 419073
Carroll Gap	In-stream benches	4,580 16,200 30,900	Carroll Gap 419006

Source: Foster 2009.

Water Management Area

Peel River—Chaffey Dam to Cockburn River

Features include in-stream benches and gravel point bars. The features in the zone between the dam wall and the Cockburn River are generally in good condition with some grazing impacts (Plates 5). This area also provides a good source of litter and organic matter.

The low-level in-stream benches require volumes of approximately 500 ML/d to inundate (NOW 2009), with higher level benches requiring between 1,000 and 4,000 ML/d. Benches higher in elevation in the reach, directly downstream of Chaffey Dam, require flows greater than the discharge capacity of the dam outlet. Inundation of these benches only occurs when the dam spills. Some benches further downstream require volumes of 2,000–5,000 ML/d to inundate.

The river channel in the zone downstream of Chaffey Dam to below the confluence of Dungowan Creek would most benefit from an increase in higher flows achieved through either a translucent or stimulus flow regime. Inundation of higher bench height thresholds could also be achieved by piggybacking dam releases onto high flows from Dungowan Creek. Extensive in-stream pool habitats are also contained in this area.

The area around Piallamore Anabranch to upstream of the confluence with the Cockburn River features a wide floodplain (plates 6 and 7). The Piallamore Anabranch, on the eastern side of the floodplain, runs for many kilometres. This anabranch is filled during high flows, however, water levels are mostly replenished by overland flows derived from adjacent hills. The channel is wider and deeper and riparian vegetation condition has suffered from grazing pressure and clearing. Lateral erosion of the banks through channel migration and avulsion may also have contributed to the reduction of vegetation in this area. More willows appear in these downstream reaches and these often cause stream blockages which results in bank erosion.

Plate 5: Peel River immediately downstream of Chaffey Dam (Foster 2003).

Plate 6: Peel River upstream of the Piallamore Anabranch (Foster 2003).

Plate 7: Peel River in the vicinity of the Piallamore Anabranch (Foster 2003).

Appendix 4
Probabilities of unregulated flows in the Namoi River at Wee Waa

Daily flows for various exceedance percentiles at Wee Waa have been determined. These are presented for each month for extreme-dry to extreme-wet scenarios. These results are based on an analysis of more than 100 years of modelled flows for current development and Water Sharing Plan rules. Annual flow totals were firstly ranked. Years corresponding to a particular climatic condition were then extracted and daily flows were then analysed to produce information on the percentage of time a flow threshold was exceeded together with the average duration (Avg D) of days above the flow threshold. This was undertaken for each month. For example, in Table 26, a January flow of 201 ML/d will be exceeded for 20 per cent of the time, with events exceeding 201 ML/d for an average duration of two days. January flow will be at least 0 ML/d (i.e. 100 per cent probability of being exceeded) with a maximum flow of about 17,778 ML/d.

It is recommended that further analysis of these events be undertaken at several sites to determine potential threshold events for the possible use of held environmental water via piggybacking.

Table 26: Probabilities of unregulated flows under extreme dry conditions—Wee Waa

	Jan		Feb		Mar		Apr		May		Jun		Jul		Aug		Sep		Oct		Nov		Dec	
	Flow	Avg D	Flow	Avg D	Flow	Avg D	Flow	Avg D	Flow	Avg D	Flow	Avg D	Flow	Avg D	Flow	Avg D	Flow	Avg D	Flow	Avg D	Flow	Avg D	Flow	Avg D
100%	0		0		36	31	21	30	15	31	33	30	0		0		0		0		2	30	0	
90%	50	9	39	27	46	21	30	30	19	31	44	30	74	28	71	23	37	13	40	23	41	23	111	20
80%	61	7	44	22	53	20	30	11	20	31	55	30	91	10	78	16	57	10	42	18	54	40	149	10
70%	70	6	54	9	59	16	31	15	22	31	60	24	127	10	96	14	86	7	50	22	88	13	178	10
60%	83	5	60	6	80	12	33	15	26	31	61	14	143	9	123	23	101	6	67	19	130	18	196	8
50%	125	4	76	9	105	11	40	19	30	31	65	16	165	10	149	10	107	6	92	13	192	13	231	7
40%	145	3	131	7	114	11	47	15	37	19	78	11	201	6	154	9	123	8	118	9	233	8	275	6
30%	167	3	191	7	182	9	82	9	60	11	90	11	219	7	194	16	134	6	165	6	264	8	315	5
20%	201	2	550	6	310	13	156	6	77	10	441	10	259	5	207	16	189	15	277	10	422	30	384	4
10%	452	4	743	2	543	7	431	8	109	8	1,551	3	346	8	664	8	588	5	468	5	1,009	3	785	5
0%	17,778	1	2,610	1	4,701	2	2,130	1	286	1	21,398	1	815	1	4,672	1	638	1	809	1	1,486	1	1,355	1

Table 27: Probabilities of unregulated flows under dry conditions—Wee Waa

	Jan		Feb		Mar		Apr		May		Jun		Jul		Aug		Sep		Oct		Nov		Dec	
	Flow	Avg D	Flow	Avg D	Flow	Avg D	Flow	Avg D	Flow	Avg D	Flow	Avg D	Flow	Avg D	Flow	Avg D	Flow	Avg D	Flow	Avg D	Flow	Avg D	Flow	Avg D
100%	0		0		0		0		19	578	0		54	31	0		0		27	31	98	30	113	31
90%	211	23	86	26	201	24	41	23	25	91	64	30	84	31	104	28	204	30	134	31	261	30	268	31
80%	407	15	311	19	305	13	54	13	35	33	77	24	109	31	186	20	337	16	186	21	364	30	507	21
70%	545	9	426	12	350	11	73	14	55	19	89	17	202	18	265	12	438	14	220	14	436	19	642	14
60%	661	7	561	10	421	10	97	10	72	13	101	11	250	12	279	9	512	12	278	15	536	14	796	17
50%	842	5	653	7	525	9	119	8	90	12	117	9	283	10	317	8	598	10	313	9	615	12	1,001	16
40%	1,023	7	738	5	617	8	153	9	110	12	137	9	324	10	380	7	698	7	333	9	761	10	1,225	10
30%	1,226	4	837	5	719	6	198	9	159	10	166	9	372	8	495	7	745	6	405	6	909	6	1,435	9
20%	1,399	3	1,046	4	898	5	258	9	201	9	244	6	574	7	840	8	824	6	474	4	1,055	5	1,672	11
10%	1,679	2	1,342	4	1,561	6	443	11	322	7	403	7	1197	7	1,437	4	1,119	4	587	4	1,453	5	2,034	7
0%	17,083	1	10,883	1	16,709	1	2,508	1	6,580	1	1,183	1	22,252	1	16,045	1	4,984	1	1,821	1	12,230	1	3,442	1

Table 28: Probabilities of unregulated flows under median conditions—Wee Waa

	Jan		Feb		Mar		Apr		May		Jun		Jul		Aug		Sep		Oct		Nov		Dec	
	Flow	Avg D	Flow	Avg D	Flow	Avg D	Flow	Avg D	Flow	Avg D	Flow	Avg D	Flow	Avg D	Flow	Avg D	Flow	Avg D	Flow	Avg D	Flow	Avg D	Flow	Avg D
100%	0		0		0		3	30	10	2696	19	30	57	31	24	31	16	30	27	31	24	30	173	31
90%	228	18	188	25	107	31	84	30	71	52	103	30	106	31	79	31	91	30	74	31	194	30	521	31
80%	399	15	318	18	186	27	128	30	107	37	138	30	201	17	201	31	276	30	274	31	369	30	730	20
70%	523	10	458	17	354	17	174	26	154	33	176	21	234	12	289	15	422	19	292	18	450	29	923	16
60%	679	9	633	10	453	16	245	20	187	29	256	22	279	12	338	13	562	16	331	16	509	25	1,117	14
50%	920	11	699	8	552	13	328	21	227	19	306	17	309	11	423	13	668	12	389	12	567	14	1,317	11
40%	1,176	7	830	6	652	10	445	19	281	19	452	22	600	20	692	12	783	9	541	14	676	10	1,565	11
30%	1,435	5	914	7	769	9	602	13	402	15	702	11	1,078	15	842	10	891	7	750	12	722	8	1,843	10
20%	1,780	5	1,148	6	959	9	1047	11	770	12	1,097	8	1,519	8	1,311	10	1,245	4	1,117	9	866	8	2,103	6
10%	2,530	4	1,982	5	1,908	5	2,289	6	2,371	9	1,840	3	2,407	7	2,735	5	1,809	3	2,100	7	1,343	5	4,031	9
0%	22,500	1	22,009	1	21,252	1	8357	1	16,027	1	4,032	1	11,998	1	6,819	1	6,085	1	15,030	1	4,974	1	22,126	1

Table 29: Probabilities of unregulated flows under wet conditions—Wee Waa

	Jan		Feb		Mar		Apr		May		Jun		Jul		Aug		Sep		Oct		Nov		Dec	
	Flow	Avg D	Flow	Avg D	Flow	Avg D	Flow	Avg D	Flow	Avg D	Flow	Avg D	Flow	Avg D	Flow	Avg D	Flow	Avg D	Flow	Avg D	Flow	Avg D	Flow	Avg D
100%	360	31	0		22	705	28	30	15	31	63	30	275	31	39	31	129	30	83	31	115	30	10	31
90%	762	22	282	27	313	22	123	27	42	31	118	30	410	31	541	31	397	30	152	31	267	30	602	31
80%	937	8	532	20	382	16	149	23	71	31	162	30	750	31	671	31	713	29	258	31	399	30	987	31
70%	1,041	7	675	12	450	15	188	24	108	28	197	30	1,745	27	1,003	31	869	19	449	27	494	21	1,233	14
60%	1,211	9	834	8	531	13	232	23	172	39	230	30	2,420	15	1,320	26	1,017	28	630	21	577	17	1,334	12
50%	1,447	10	960	7	649	10	299	18	322	25	519	24	2,926	10	1,870	19	1,356	14	884	16	727	13	1,441	9
40%	1,783	8	1,103	6	734	9	443	18	567	20	659	13	3,549	9	2,314	14	1,563	10	1,181	11	1,147	10	1,656	8
30%	1,992	4	1,280	6	868	6	631	18	827	17	1,237	14	5,116	10	2,702	10	1,699	9	1,544	9	1,664	11	1,894	6
20%	2,304	4	1,758	8	1,388	8	1,124	9	1,492	12	2,565	7	7,076	8	3,667	8	1,858	7	2,250	9	2,592	8	2,201	9
10%	4,125	5	3,535	6	2,952	6	2,298	7	5,176	6	5,609	7	18,257	6	5,857	7	3,694	8	4,475	6	4,789	7	3,991	9
0%	32,741	1	19,425	1	86,582	1	85,728	1	21,071	1	61,315	1	69,042	1	42,100	1	17,715	1	23,950	1	16,527	1	36,213	1

Table 30: Probabilities of unregulated flows under extreme wet conditions—Wee Waa

	Jan		Feb		Mar		Apr		May		Jun		Jul		Aug		Sep		Oct		Nov		Dec	
	Flow	Avg D	Flow	Avg D	Flow	Avg D	Flow	Avg D	Flow	Avg D	Flow	Avg D	Flow	Avg D	Flow	Avg D	Flow	Avg D	Flow	Avg D	Flow	Avg D	Flow	Avg D
100%	237	31	195	27	136	31	170	30	172	31	152	30	37	31	47	31	65	30	22	31	435	30	431	31
90%	538	12	340	27	388	31	571	30	234	31	311	30	150	18	173	28	342	23	312	31	534	30	1,092	18
80%	698	9	543	27	840	24	697	17	316	31	339	30	234	31	308	31	417	17	381	31	845	30	1,241	13
70%	896	10	685	27	1,368	16	744	26	371	31	381	26	344	27	341	21	527	21	518	29	1,769	18	1,327	10
60%	1,128	11	871	14	2,019	14	922	18	548	31	683	23	443	31	587	19	667	15	626	22	2,142	13	1,478	7
50%	1,717	8	1,281	18	2,770	15	1,088	15	872	26	1,071	19	1,006	16	869	16	747	10	807	28	2,776	15	1,591	6
40%	1,977	6	8,594	14	3,582	15	1,286	12	1,141	16	3,101	20	1,305	8	1,980	13	865	10	2,517	21	3,434	8	1,680	5
30%	2,217	4	22,481	8	6,116	12	1,765	8	7,404	16	4,159	11	1,693	7	2,719	12	1,755	8	3,288	7	4,167	9	1,819	4
20%	2,980	6	54,669	7	8,260	9	2,371	8	12,363	5	5,635	8	2,031	6	6,428	16	5,000	16	5,164	6	5,754	5	2,006	6
10%	6,235	3	104,613	5	35,148	6	5,186	8	22,001	4	10,717	4	3,317	6	23,447	5	18,426	15	8,029	5	8,133	4	2,604	3
0%	35,449	1	285,310	1	307,390	1	25,862	1	76,317	1	42,423	1	219,580	1	136,120	1	87,837	1	66,181	1	47,993	1	4,990	1

Appendix 5
Water order application form

Water Order Application Form

In accordance with the Water Management Act 2000 and Water Act 1912

Clear Form | Print

Part 1 - Water order Type

New Water Order ☐ | Amend existing order ☐ | Cancel existing order ☐

Meter Reading Only ☐ | Date original order submitted: __ __ / __ __ / __ __ __ __

Part 2 - Water Access Licence Details

Licence Holder Name:

Licence Number: eg. 50AL000001 or 60AL000001 or 70AL000001

Part 3 - Combined Approval or Works Approval Details

CA or WA Number : eg. 50CA000001 or 60WA000001 or 70WA000001

Extraction Site: eg. ESID or meter number or pump description.

Part 4 - Extraction Details

Bulk Order
Orders that will not vary on a daily basis

or

Daily Order
For orders that vary volume on a daily basis.

Start Date	__ __ / __ __ / __ __ __ __
Number of Days Pumping	
Volume per day	ML

Start date **MUST** comply with lag day requirements and cannot exceed a period of one month.

Date	ML/Day

Part 5 - Current Meter Reading(s)

Date	*Pump Description*	*Reading*

Part 6 - Authorisation declaration (Mandatory)

☐ I am/we are authorised to make this application on behalf of the holder(s) of this licence.

Name(s):

Signature: | Application Date: __ __ / __ __ / __ __ __ __

Phone: | Fax:

How to submit this form *Enquiries please call 1300662077*

Fax to: 1300871447 Email:
North.Orders@statewater.com.au - Gwydir, Namoi, Borders Rivers
Central.Orders@statewater.com.au - Macquarie, Lachlan, Hunter, Coastal
South.Orders@statewater.com.au - Murray\Lower Darling, Murrumbidgee

Please keep a copy of completed form for your record

Appendix 6
SEWPaC risk matrix

LIKELIHOOD	CONSEQUENCE **Insignificant** No environmental damage.	**Minor** Minor instances of environmental damage that could be reversed.	**Moderate** Isolated but significant instances of environmental damage that might be reversed with intensive efforts.	**Major** Severe loss of environmental amenity and danger of continuing environmental damage.	**Critical** Major widespread loss of environmental amenity and progressive irrecoverable environmental damage.
Almost certain Is expected to occur in most circumstances.	Low	Medium	High	Severe	Severe
Likely Will probably occur in most circumstances	Low	Medium	Medium	High	Severe
Possible Could occur at some time	Low	Low	Medium	High	Severe
Unlikely Not expected to occur	Low	Low	Low	Medium	High
Rare May occur in exceptional circumstances only	Low	Low	Low	Medium	High

Appendix 7
Operational monitoring report

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)[7]	
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*[8]	

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

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


WAT214.0211