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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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.

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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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).

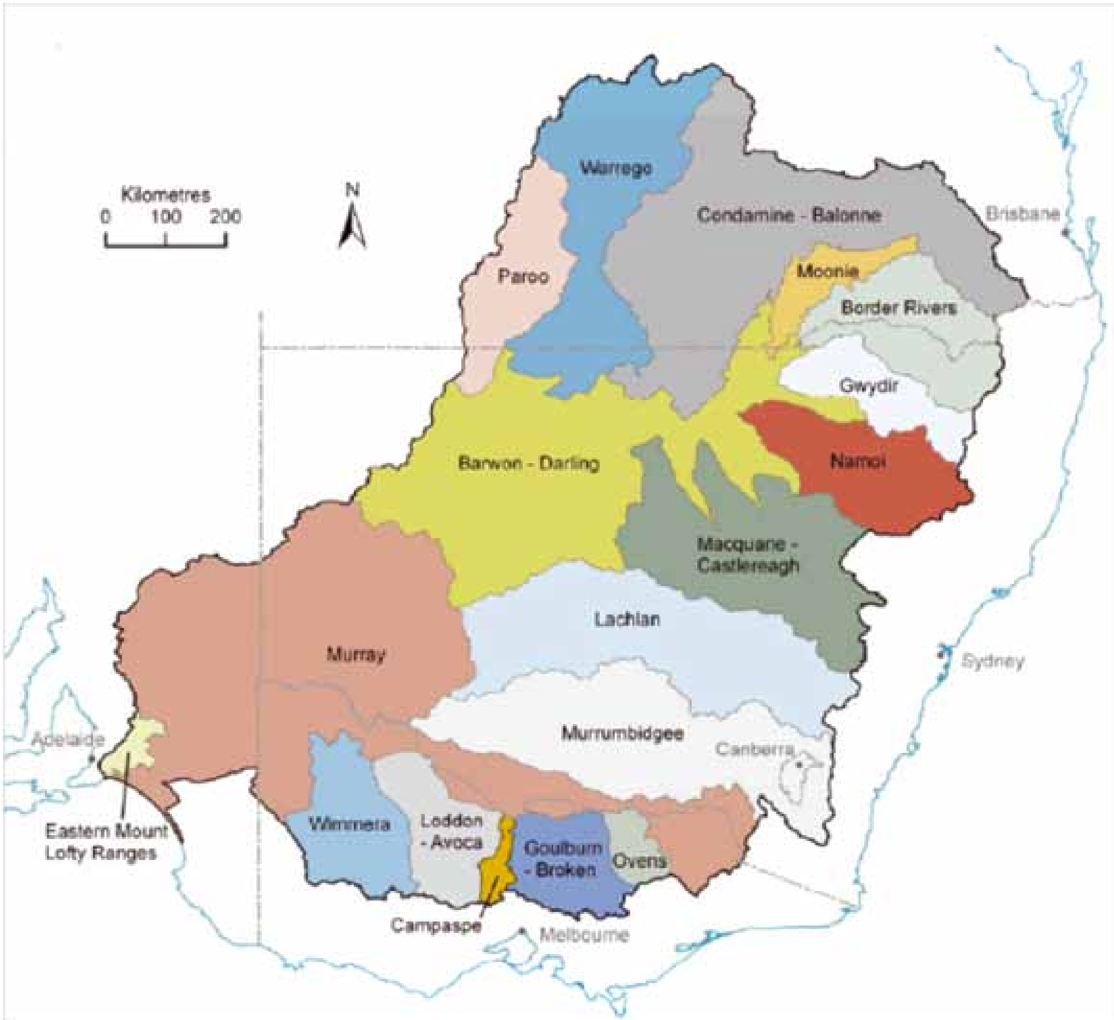


Figure 1: Location of the Murrumbidgee River catchment in the Murray-Darling basin. (Source: CSIRO 2008)

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.

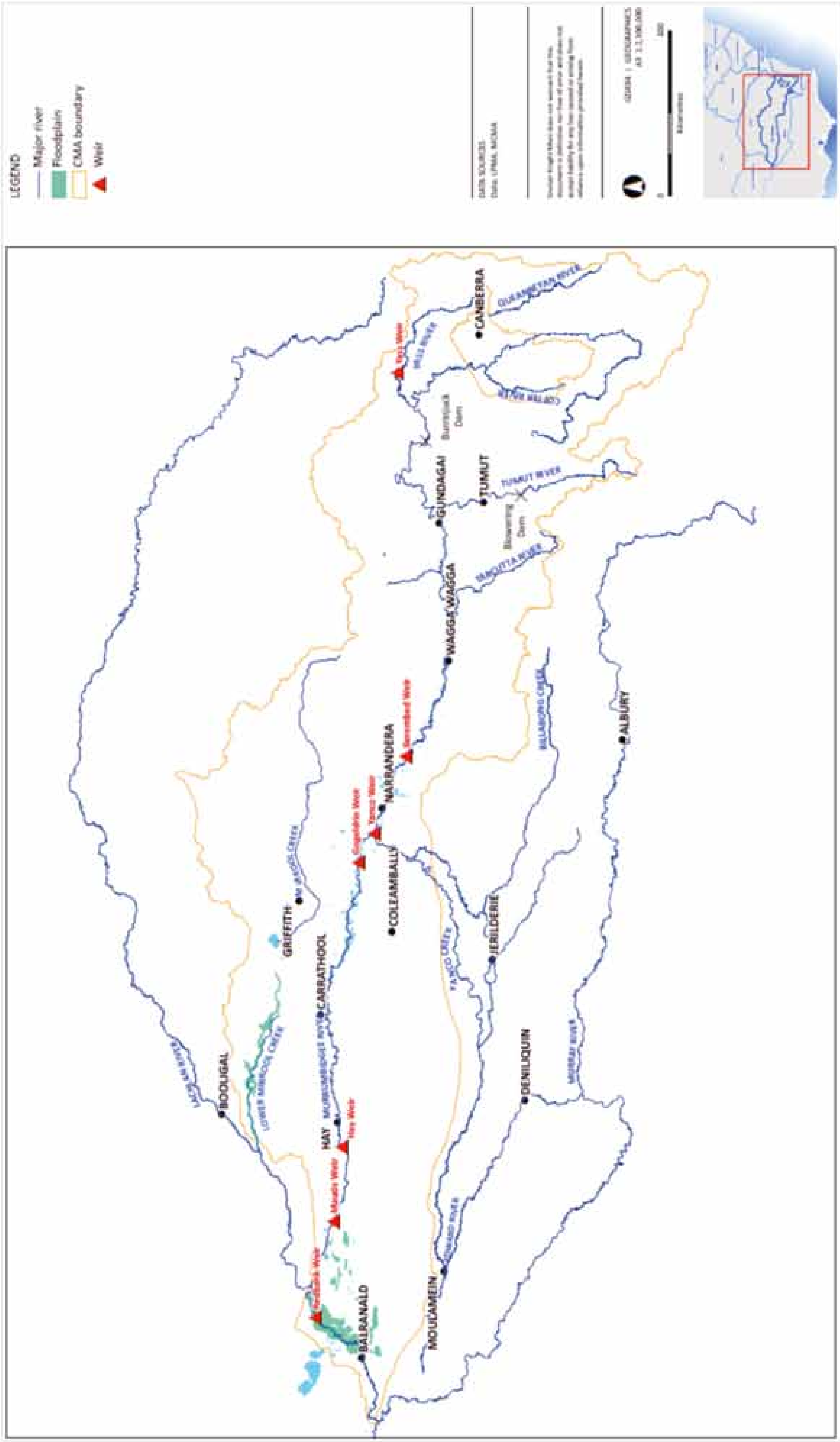


Figure 2: Murrumbidgee River catchment.

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.

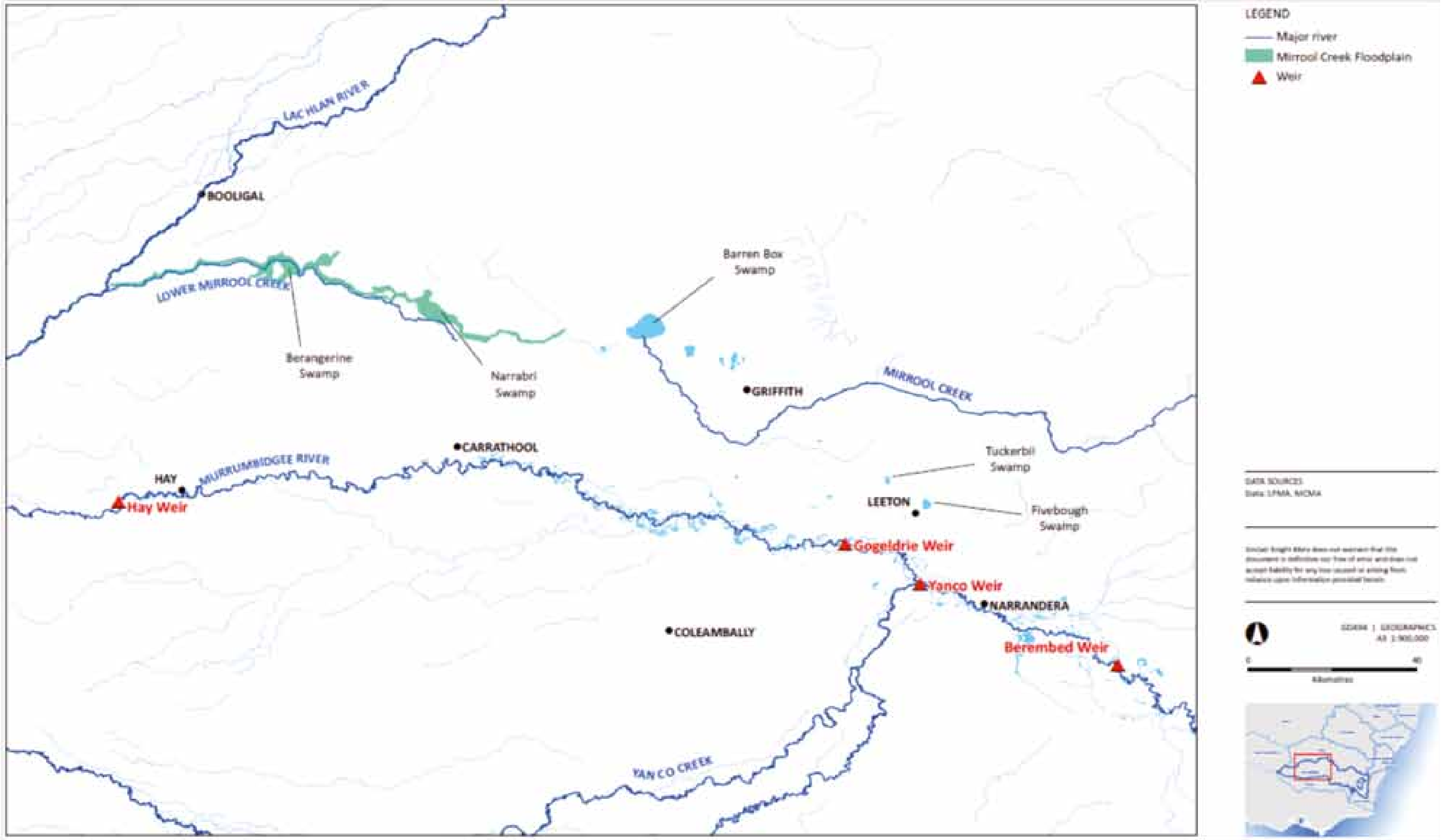


Figure 3: The Mirrool Creek system.

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).

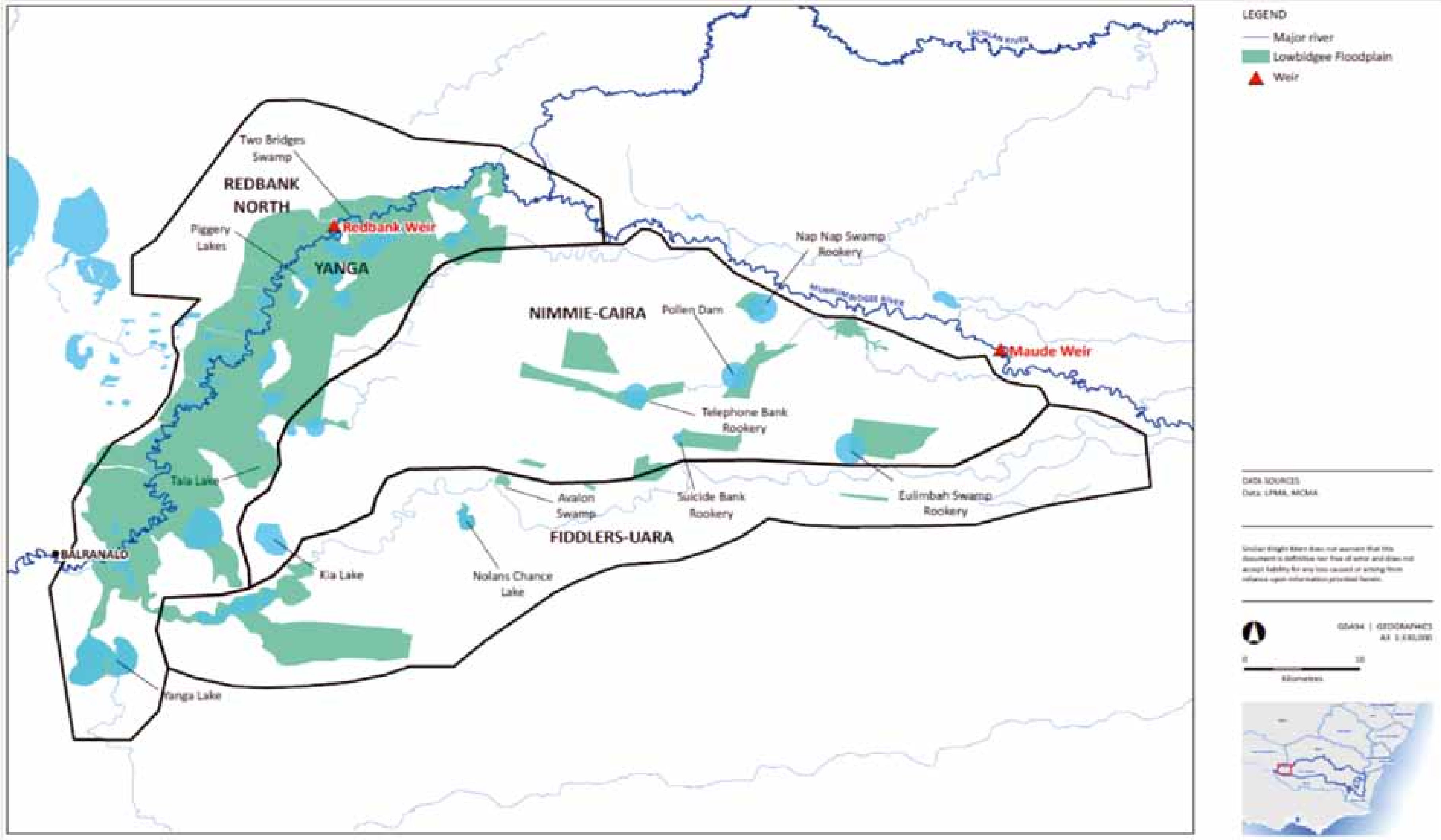


Figure 4: The Lowbidgee Floodplain.

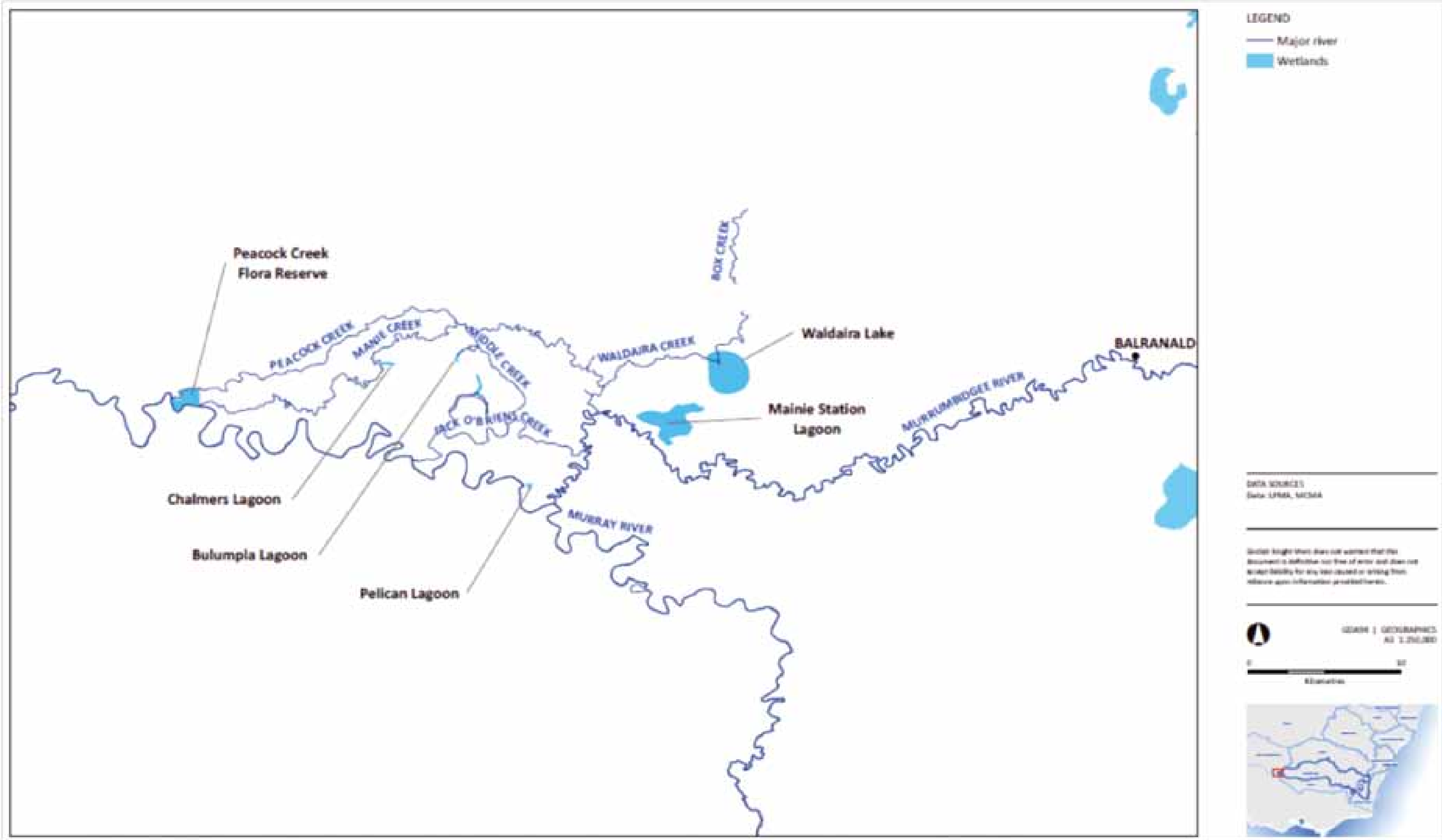


Figure 5: Floodplain wetlands—Balranald to the Murray River junction.

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.

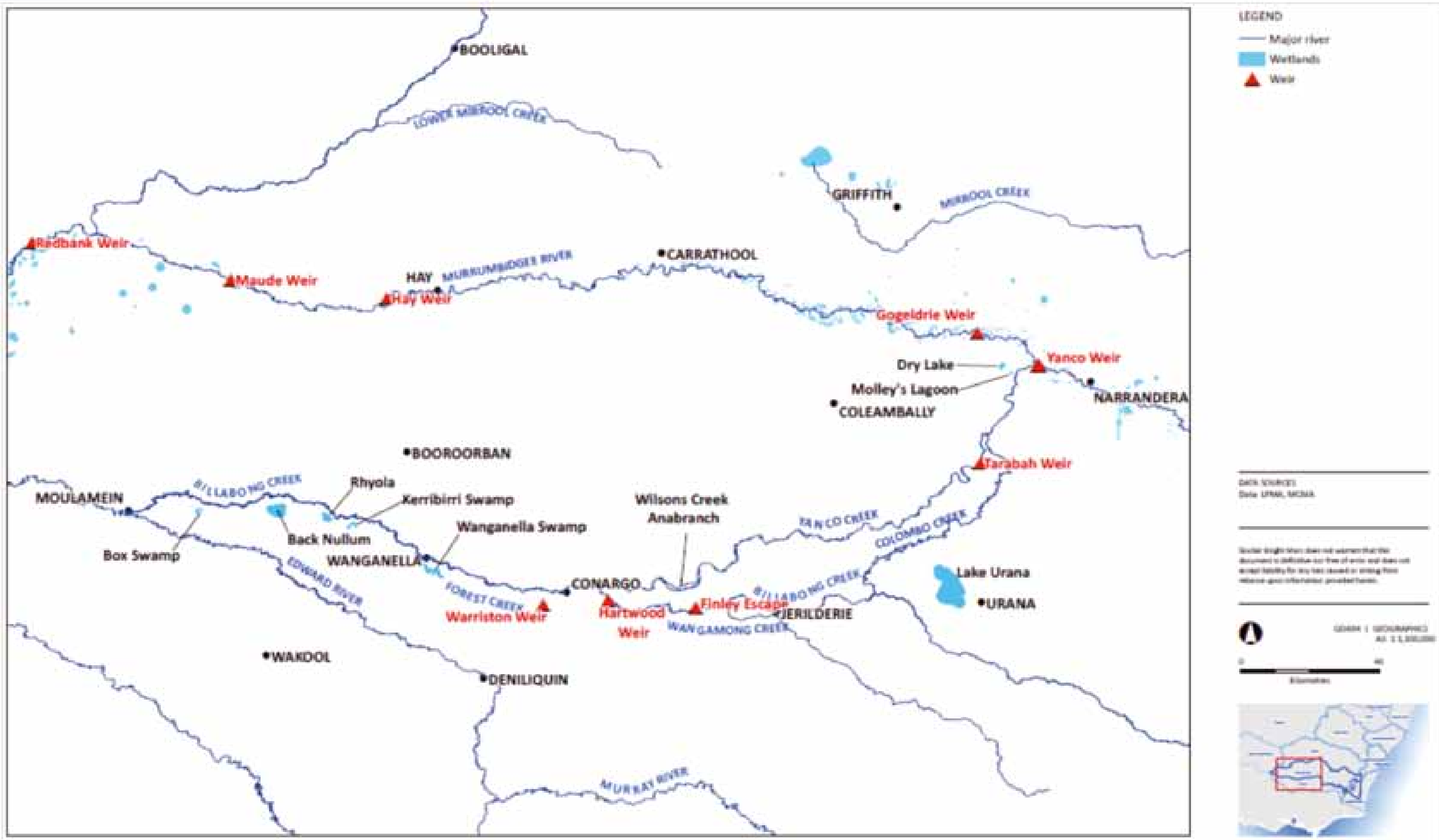


Figure 6: The Yanco Creek system.

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	30th Percentile Year	50th Percentile Year	70th 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).

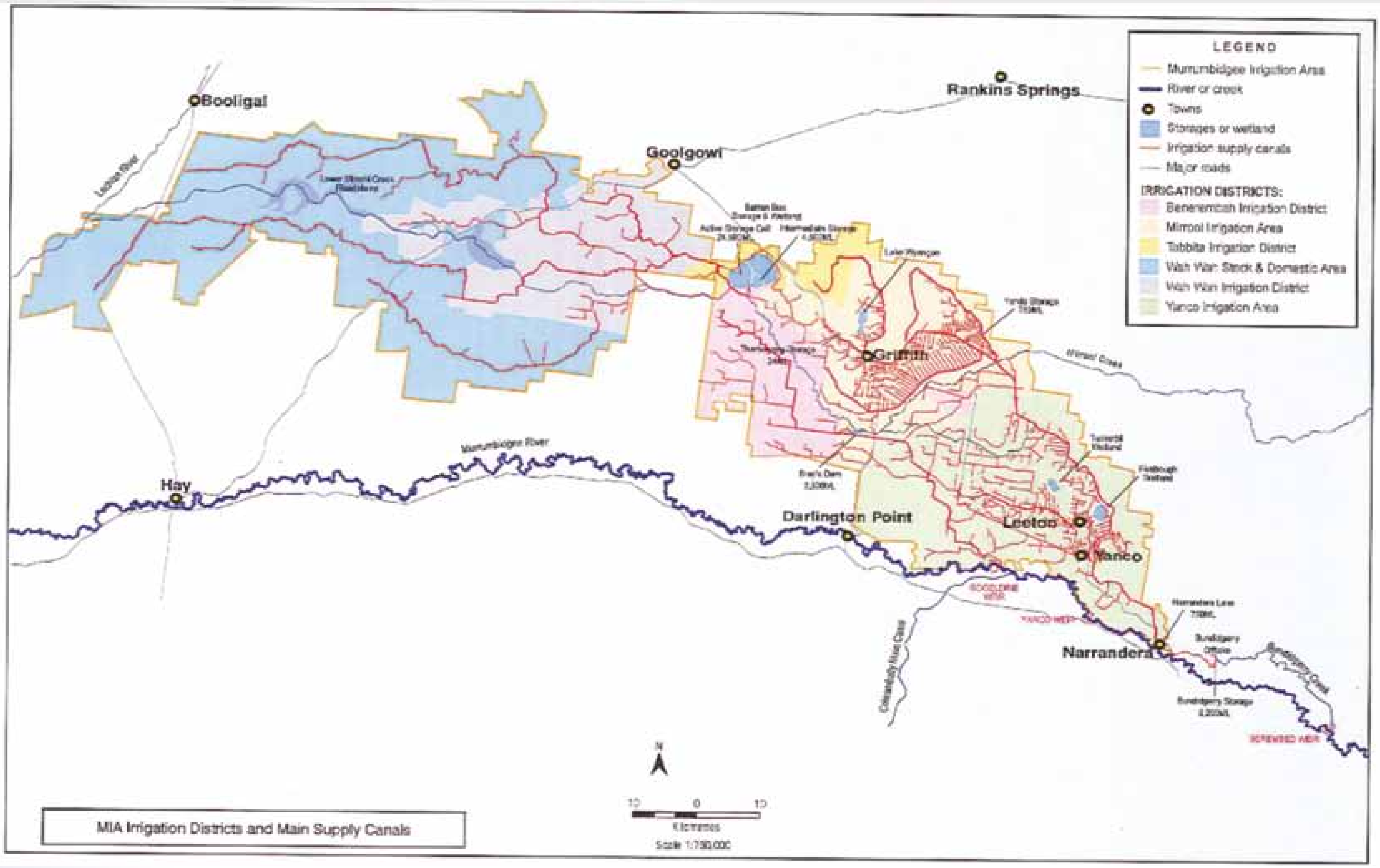


Figure 7: Murrumbidgee Irrigation Area and the Mirrool Creek catchment. (Source: MI 2007)

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.

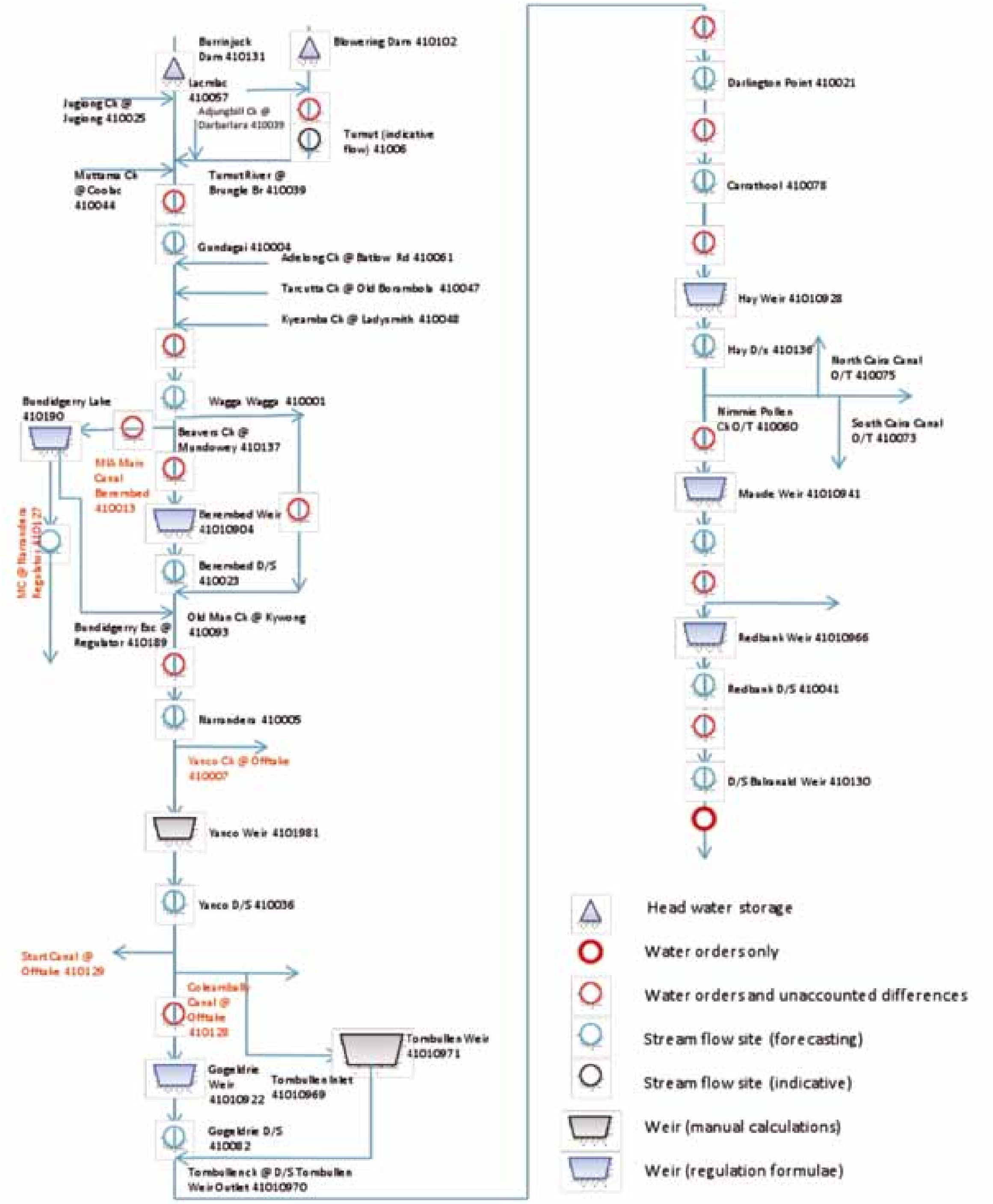


Figure 8: Schematic of the location of dams, regulators and weirs in the Murrumbidgee River catchment.

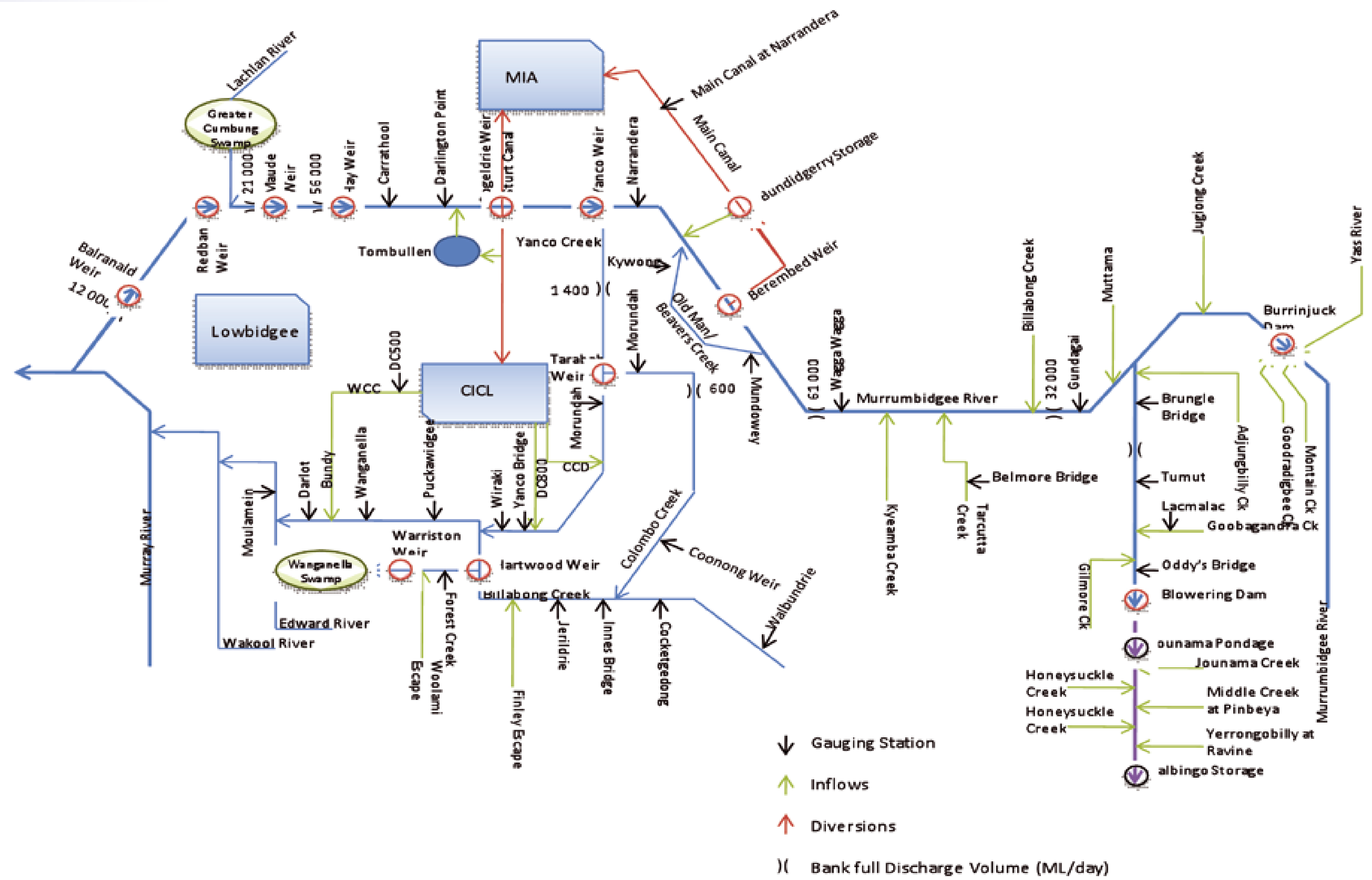


Figure 9: Schematic of the Tumut River and the Yanco Creek system operational environment.

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.

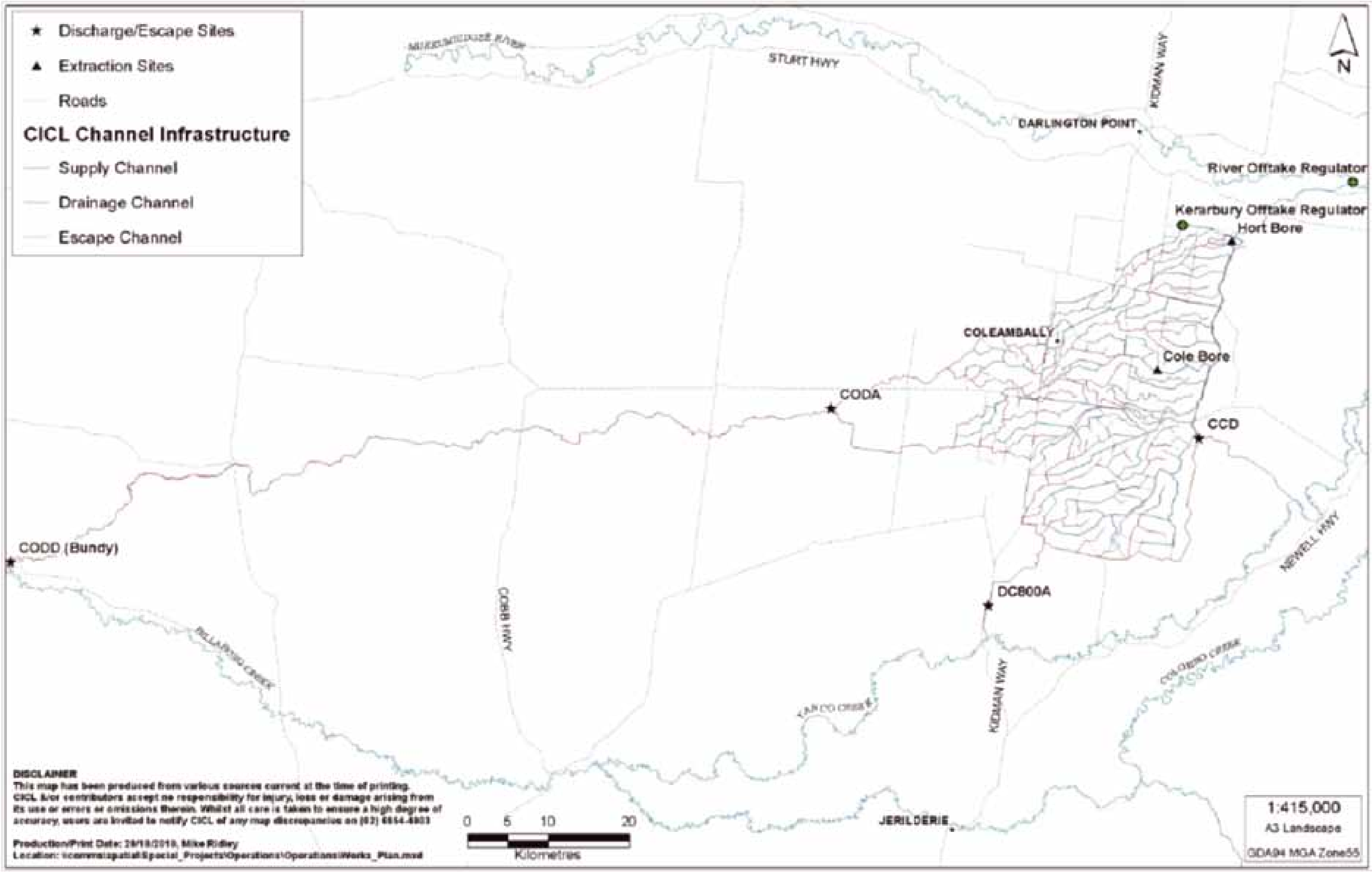


Figure 10: Coleambally Irrigation supply network. Note, WCC is marked on the figure as COD (Coleambally Outfall Drain). (Source: Coleambally Irrigation 2010)

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.

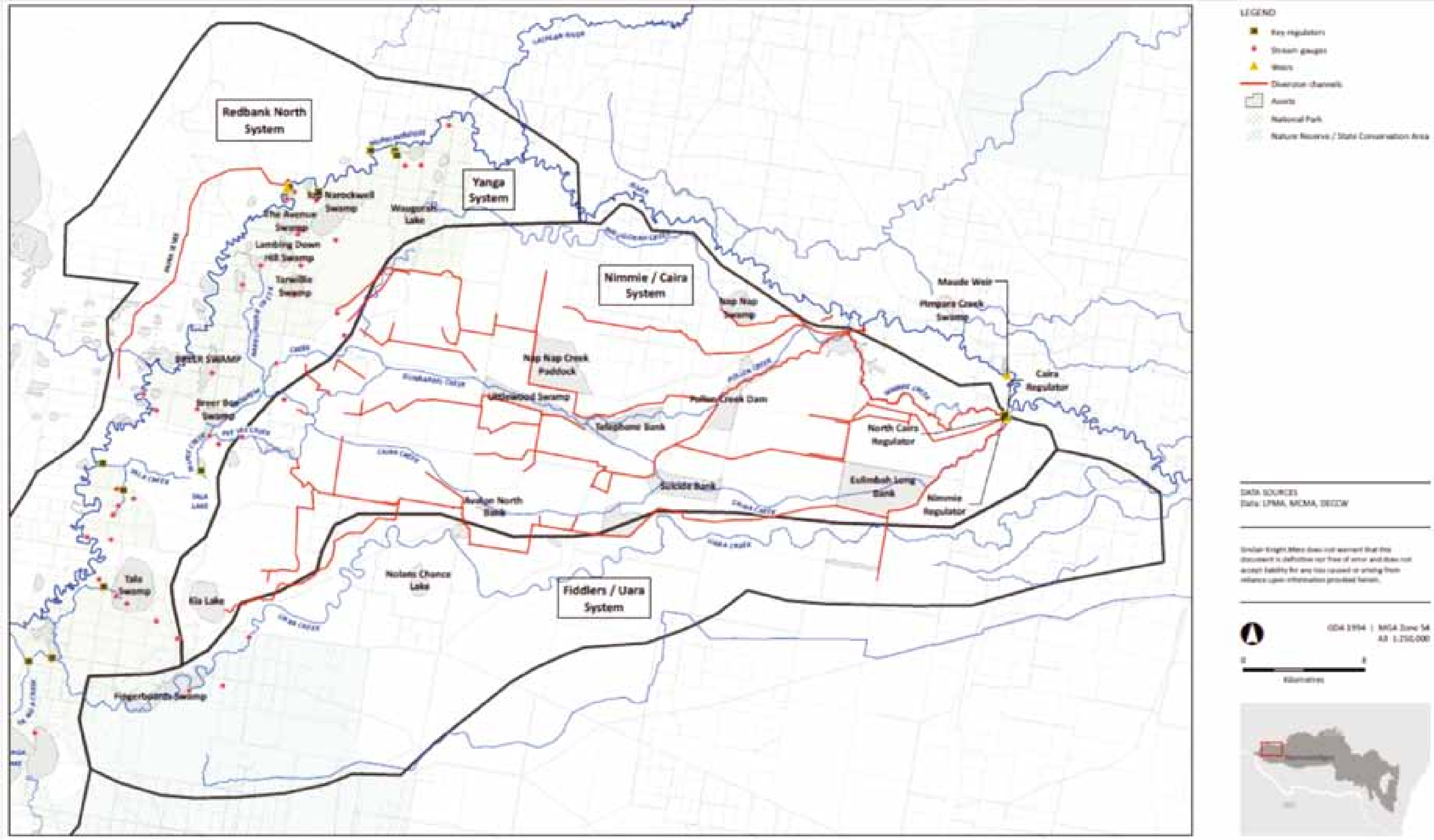


Figure 11: The location of key assets in the Lowbidgee.

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.

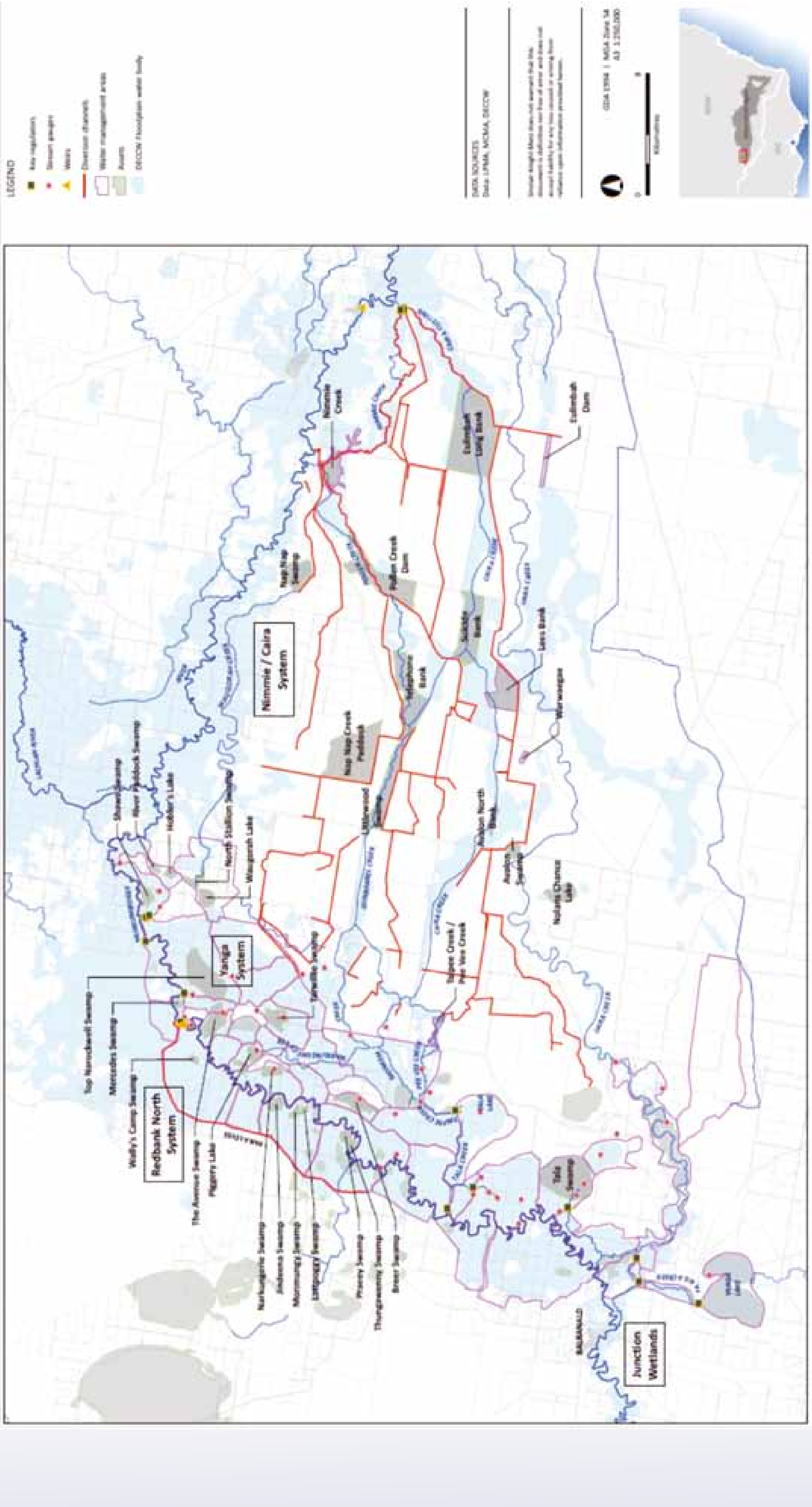


Figure 12: The Nimmie-Caira channel system.

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.

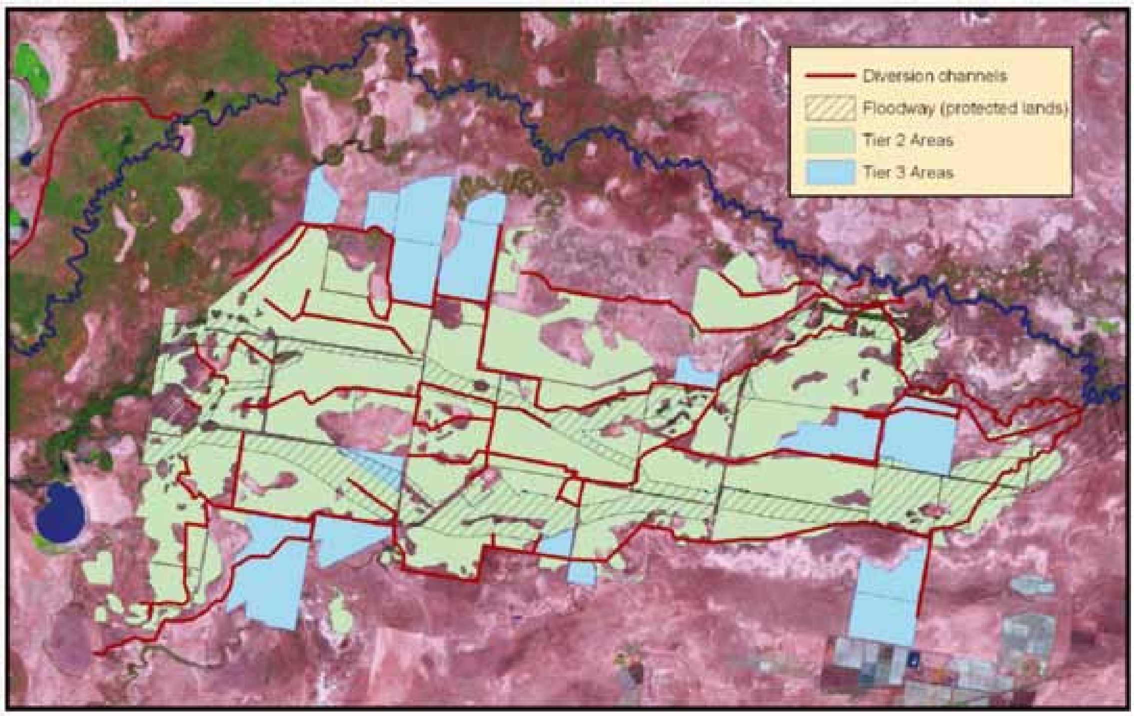


Figure 13: Nimmie-Pollen League tiered allocation and protected lands.

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.

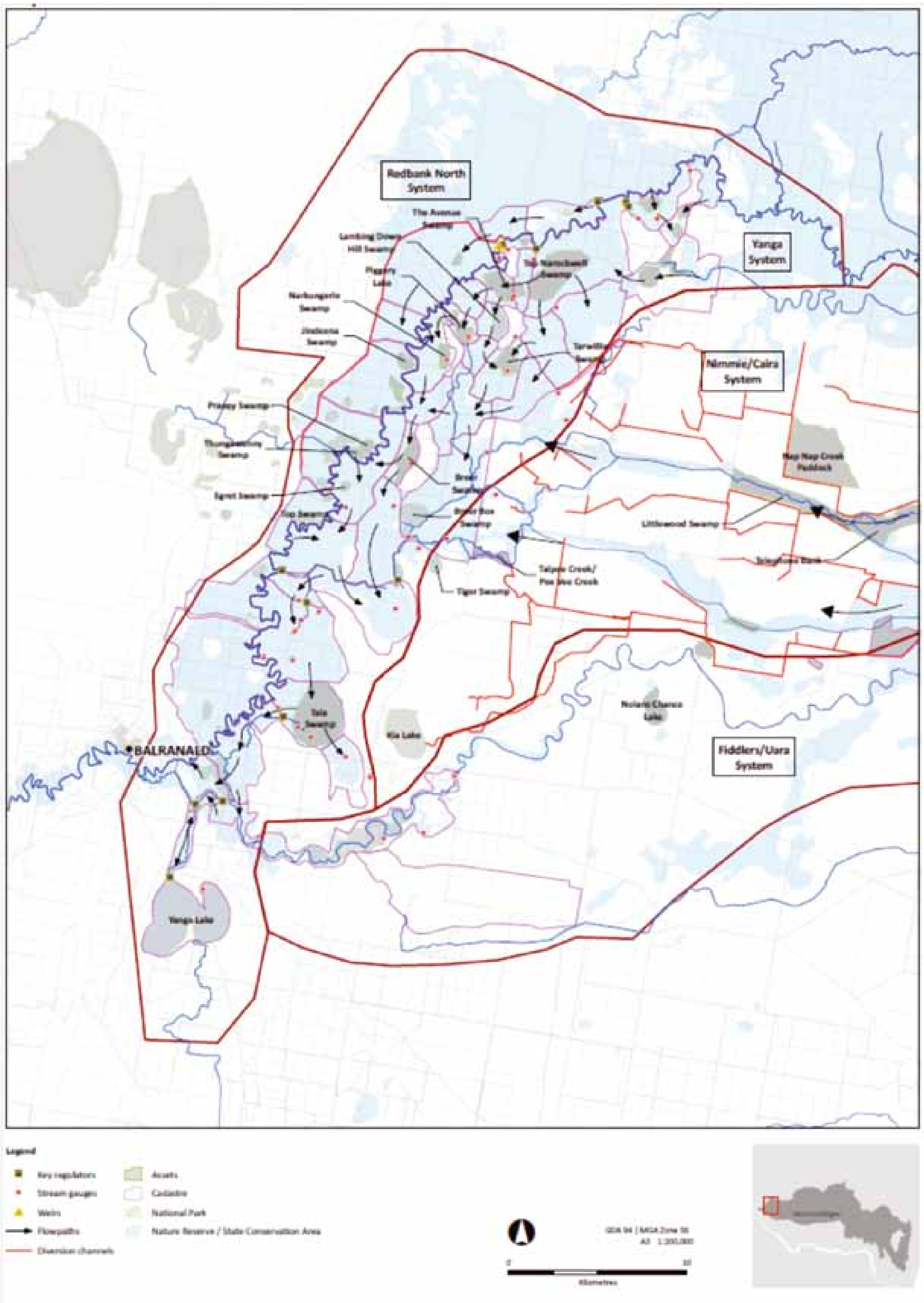


Figure 14: Main flowpaths and regulators in Yanga.

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.

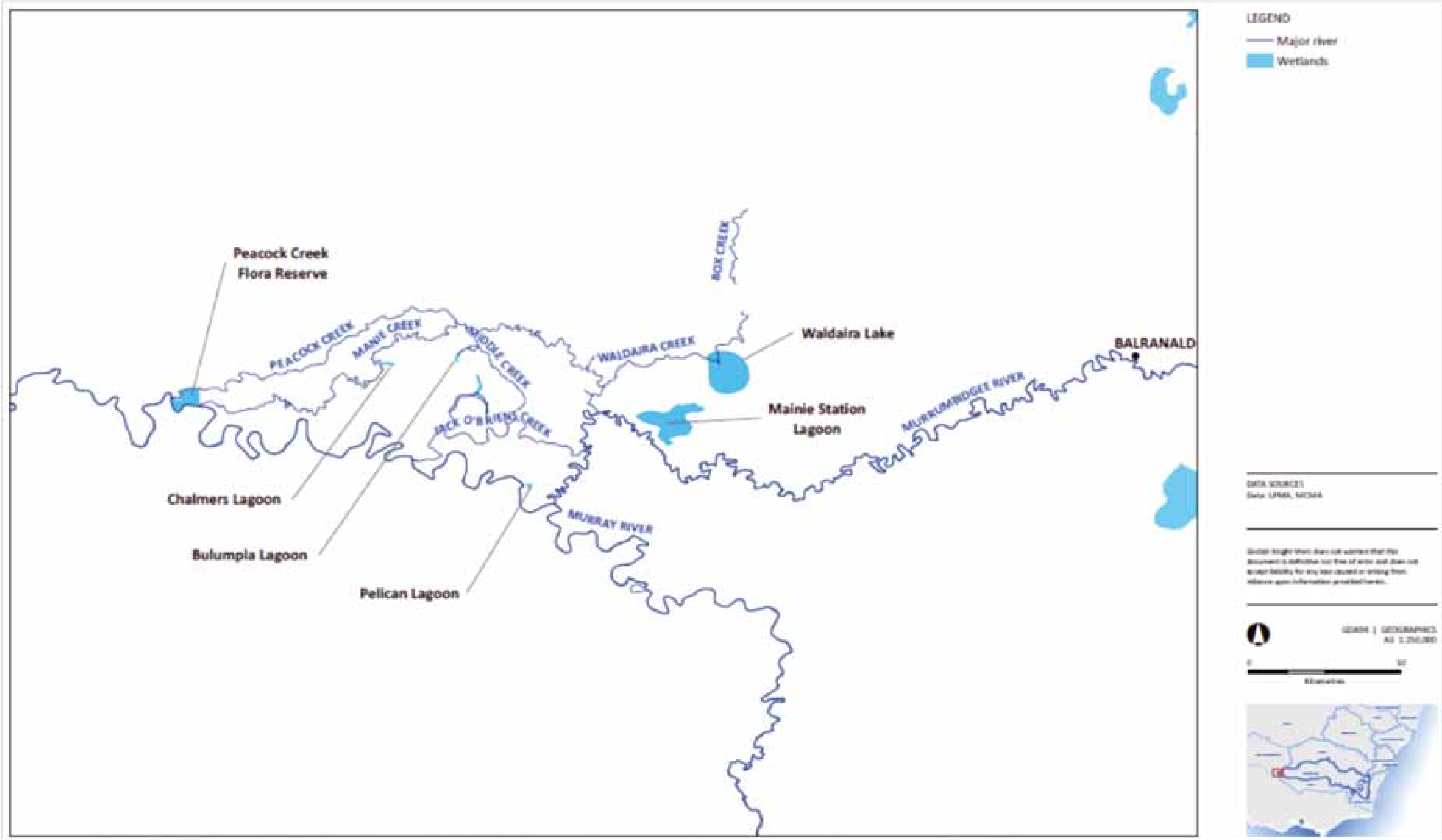


Figure 16: Location of key creeks and lagoons in the Balranald to Murray Junction reach of the Murrumbidgee River.

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

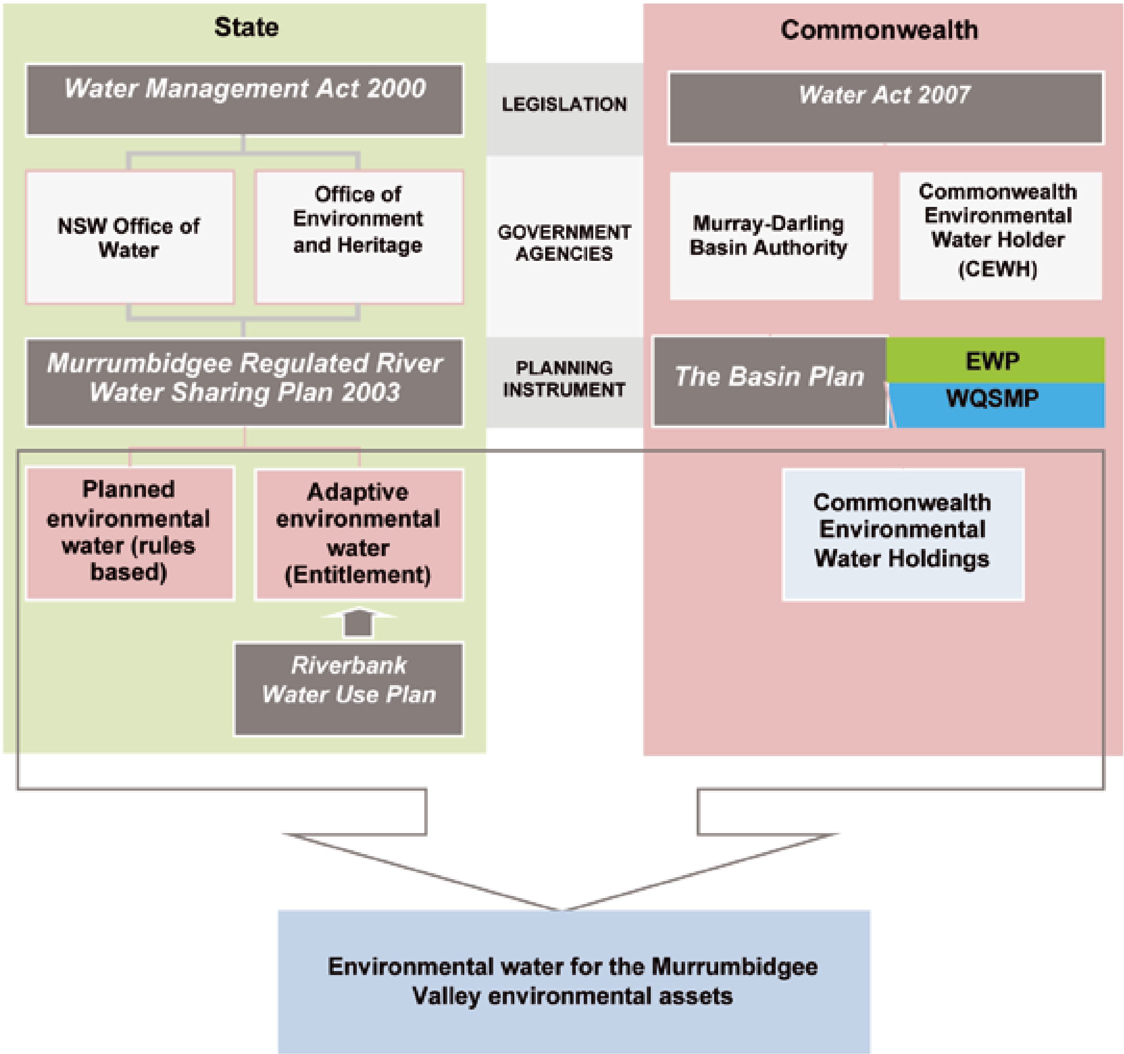
5.1 Overview of legislative instruments and policies

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

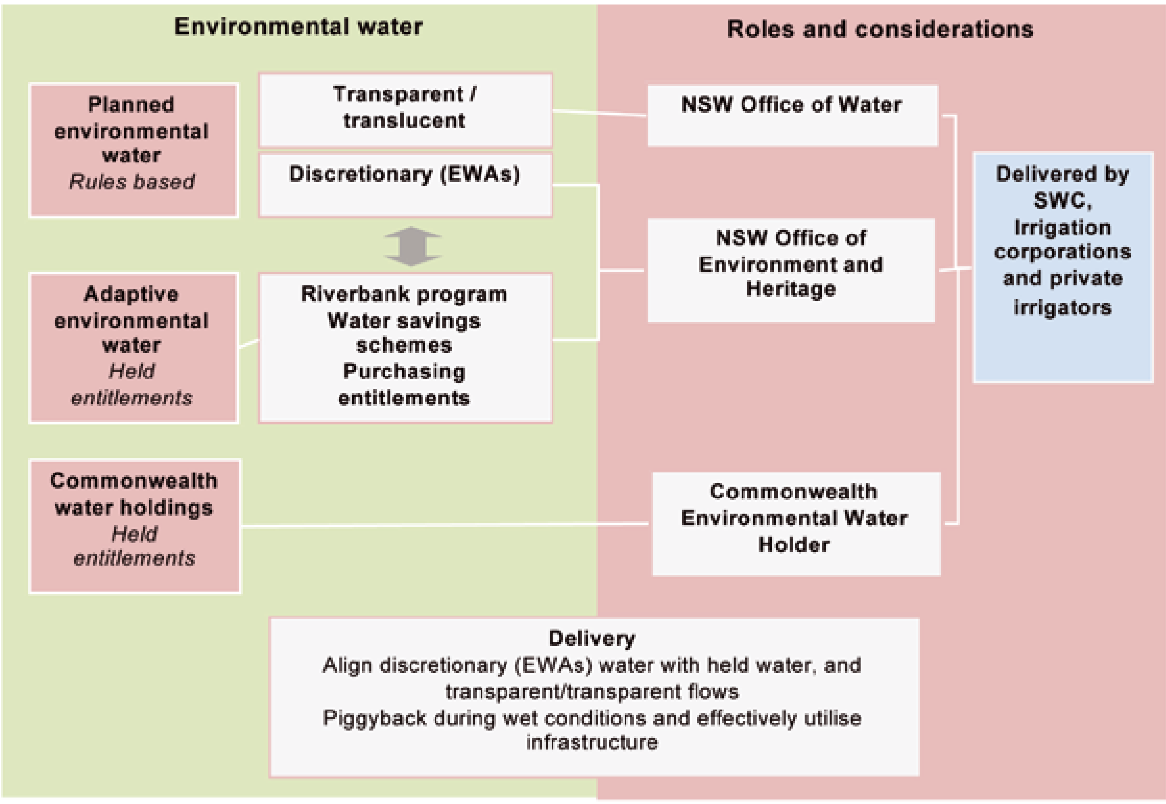
j) protect identified indigenous and traditional uses of water

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.

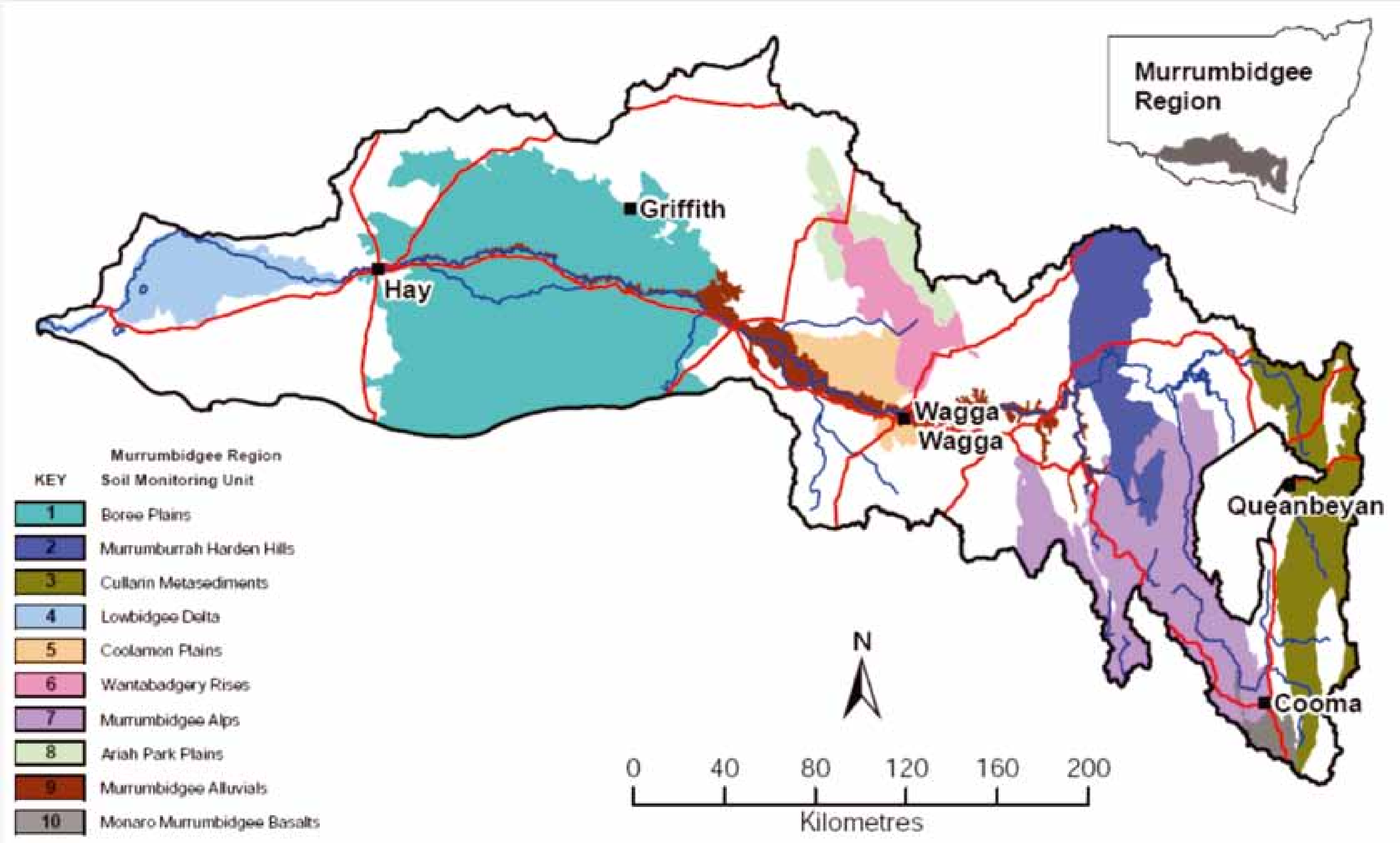


Figure 19: Soil management units for the Murrumbidgee catchment. (Source: OEH 2010b)

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 (30^{th} percentile daily flow)	Median year (50^{th} percentile daily flow)	Wet year (70^{th} 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