Australian Government

Commonwealth Environmental Water

ENVIRONMENTAL WATER DELIVERY:
Edward Wakool System

MAY 2011 V1.1

Image Credits

Wakool River at Calimo Road
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Juvenile straw-necked ibis, Wanganella Swamp
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V1.1 Updated in September 2011 to include a correction.

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Environmental Water Delivery: Edward-Wakool

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

- community views on environmental assets and the health of these assets;
- views on the prioritisation of environmental water use;
- potential partnership arrangements for the management of environmental water; and
- possible arrangements for the monitoring, evaluation and reporting (MER) of environmental water use.

This document has been prepared to provide information on the environmental assets and potential environmental water use in the Edward-Wakool system.

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

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

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

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

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Acronyms

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

PART 1:
Management Aims

1. Overview

1.1 Scope and purpose of this document

Information provided in this document is intended to help establish an operational planning framework that provides scalable strategies for environmental water use based on the demand profiles for selected assets. This document outlines the processes and mechanisms that will enable water use strategies to be implemented in the context of river operations and delivery arrangements, water trading and governance, constraints and opportunities. It specifically targets water use options for large volumes of environmental water.

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

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

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

1. Existing information for selected environmental assets has been collated to establish asset profiles, which include information on hydrological requirements and the management arrangements necessary to deliver water to meet ecological objectives for individual assets.
2. Water use options have been developed for each asset to meet watering objectives under a range of volume scenarios. Efforts are also made to optimise the use of environmental water to maximise environmental outcomes at multiple assets, where possible. In the first instance, water use strategies will provide an 'event ready' basis for the allocation of Commonwealth environmental water in the 2011 autumn and spring seasons. These strategies will be integrated into a five-year water delivery program.

3. Processes and mechanisms that are required to operationalise environmental water use strategies are documented and include such things as:
   - delivery arrangements and operating procedures;
   - water delivery accounting methods that are either currently in operation at each asset or methodologies that could be applied for accurate accounting of inflow, return flows and water 'consumption';
   - decision triggers for selecting any combination of water use options; and
   - approvals and legal mechanisms for delivery and indicative costs for implementation.

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

1.2 Catchment and river system overview

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

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

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

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

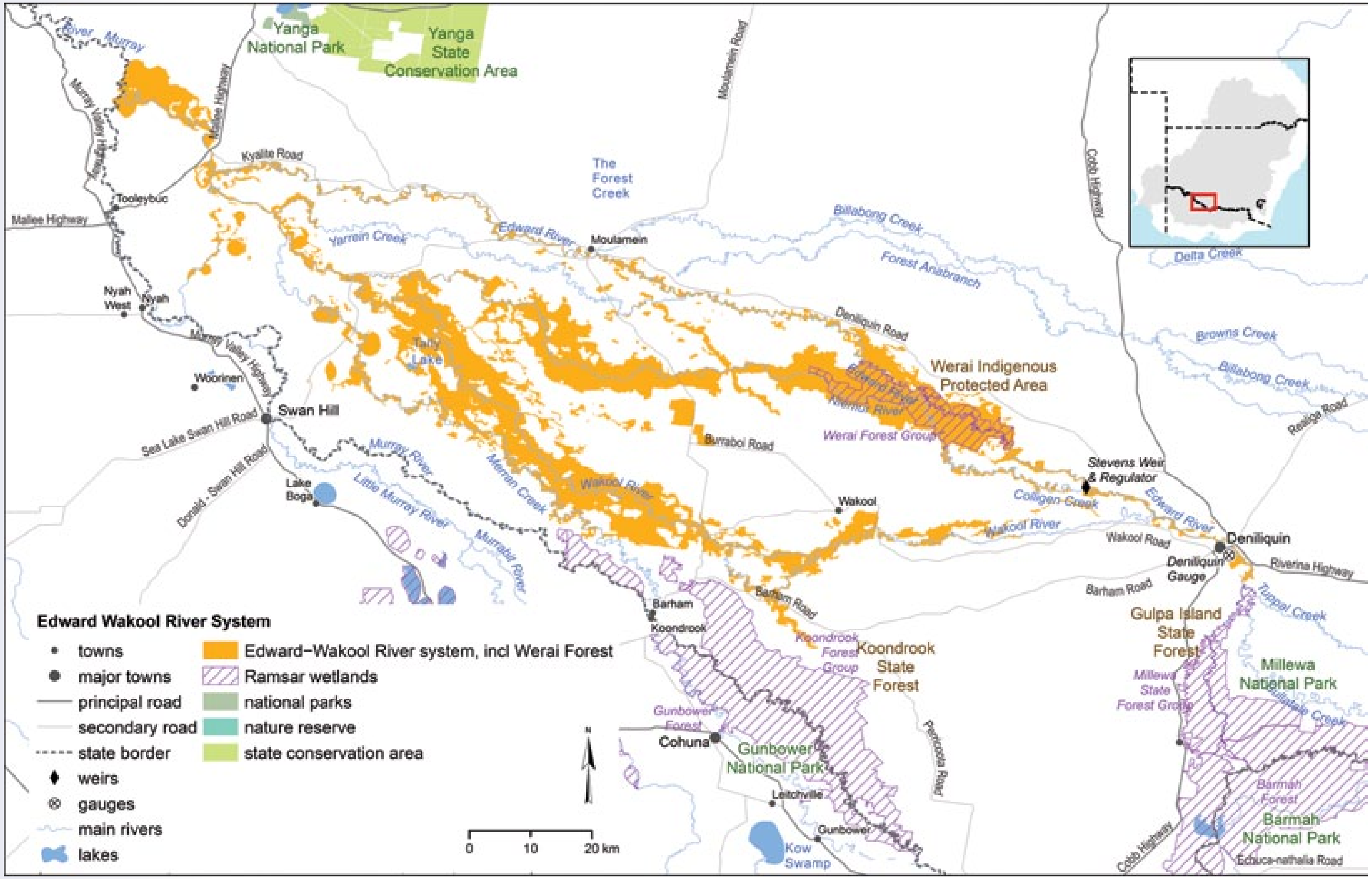

Figure 1: Location of the Edward-Wakool System (MDBA 2010a).

1.3 Overview of river operating environment

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

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

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

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

During flood flow conditions the gates at Stevens Weir are lifted clear of the water, reducing flow impedance. Additional distributary creeks from the River Murray, such as Tuppal and Bullatale Creeks, can commence to flow and become a major source of water entering the Edward River. During large floods, the volume flowing through the Edward-Wakool system in some locations can be in the order of five times that flowing through the River Murray.

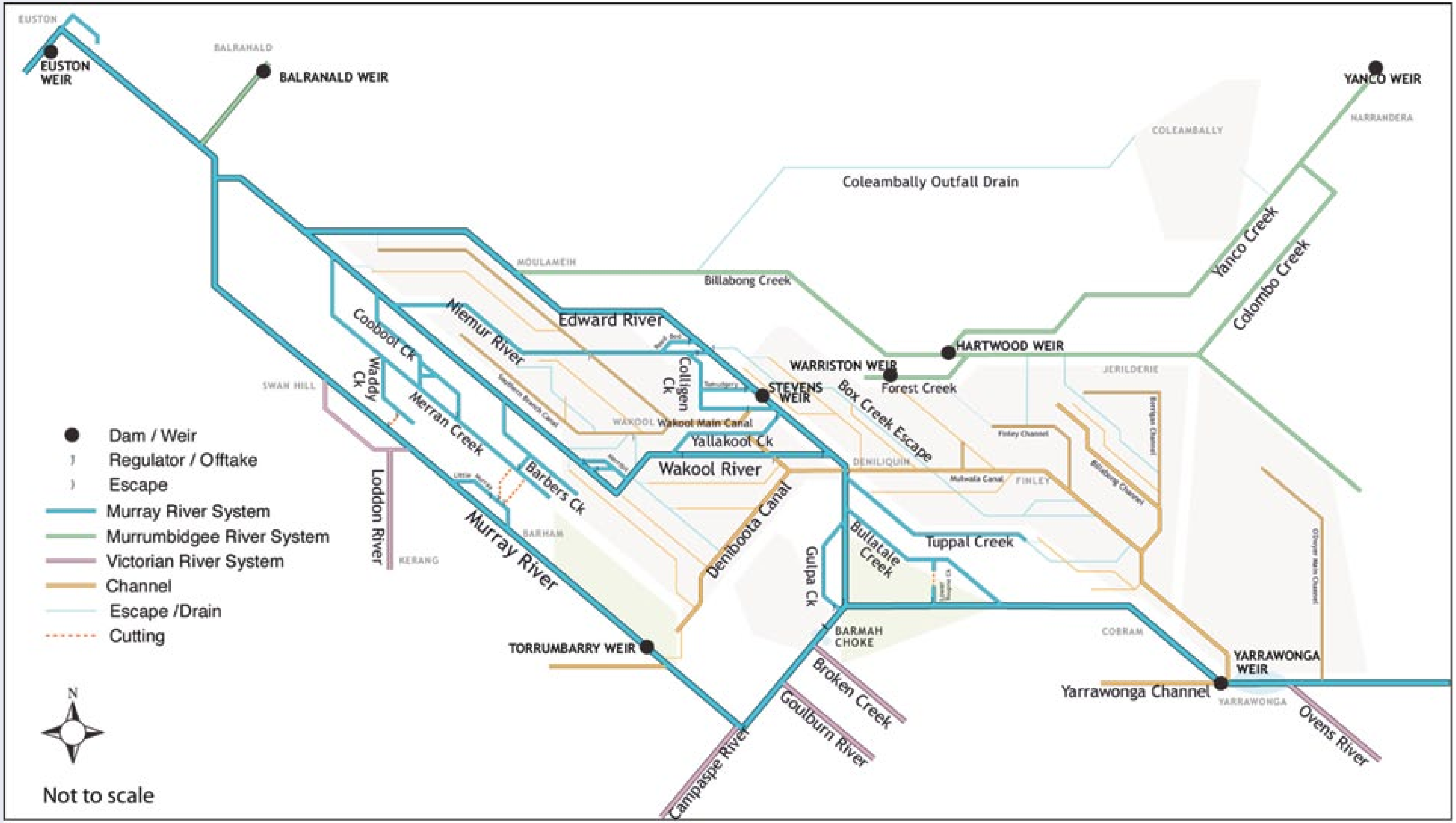

Figure 2: Edward-Wakool River system (adapted from DWE 2009).

2. Ecological values, processes and objectives

2.1 Ecological values

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

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

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

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

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

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

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

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

2.2 Ecological objectives

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

1 Fishway currently under construction

Table 1: Ecological objectives for targeted water use

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

3. Watering objectives

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

The watering objectives for the Edward-Wakool are based on information derived from a number of sources, which are outlined briefly below.

Modelling undertaken by MDBA (2010a) provides a valuable basis for defining watering objectives for the Edward-Wakool. This modeling was primarily based on the ecological requirements of the system – specifically, the water requirements of the major vegetation associations (Figure 3) and colonial waterbirds (Table 3). However, this modeling did not account for the operational constraints inherent in the system.

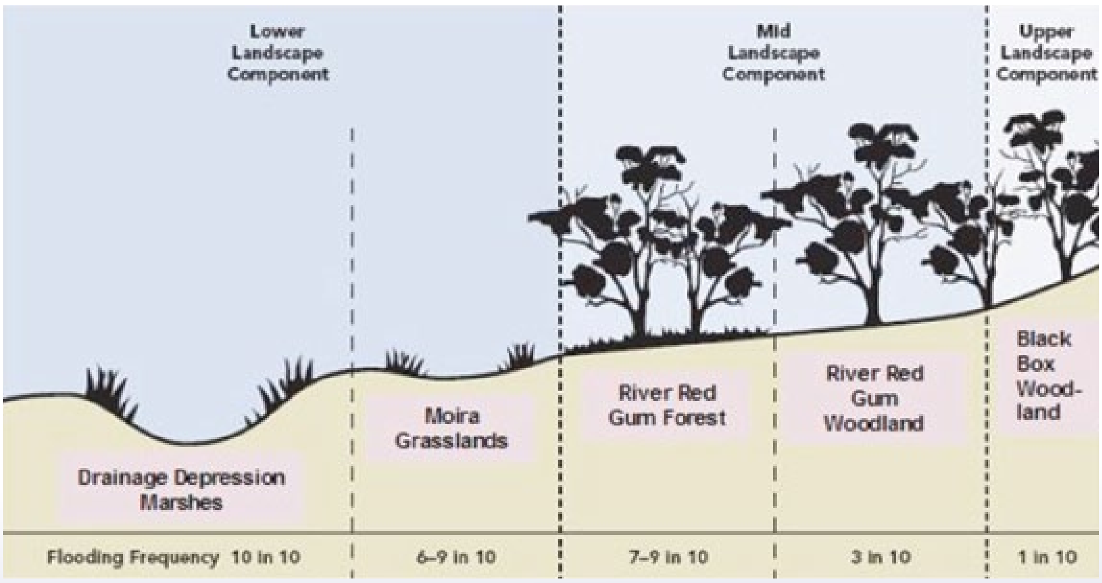

Figure 3: Vegetation associations, geomorphic setting and flood regime (adapted from MDBC 2007 in Harrington and Hale in prep.).

Table 2: Water use management objectives (all flows are quoted for the Edwards River at Deniliquin)

	Management objectives for specific water availability scenarios			
	Extreme dry Goal: Avoid damage to key ecological assets	**Dry** Goal: Ensure ecological capacity for recovery	**Median** Goal: Maintain ecological health and resilience	**Wet** Goal: Improve and extend healthy aquatic ecosystems
Water availability	Minimum allocation on record	30th percentile year	50th percentile year	70th percentile year
Permanent, semi-permanent regulated rivers and creeks (>1,000 km).				
	Minimum of 1,500 ML/day at Deniliquin from mid August to November: Maintain water quality within channels and pools. Reduce the frequency and magnitude of blackwater events, by preventing the accumulation of litter in channel and on bars and benches. Prevent stratification in shallow pools; and ensure stratification in deep pools is not broken. Maintain inundation of wetlands connected at pool level to minimise exposure of ASS.	Minimum of 1,500 ML/day at Deniliquin from July to November: Maintain water quality within channels and pools. Reduce the frequency and magnitude of blackwater events, by preventing the accumulation of litter in channel and on bars and benches. Prevent stratification in shallow pools and ensure stratification in deep pools is not broken. Maintain inundation of wetlands connected at pool level to minimise exposure of ASS.	Minimum of 1,500 ML/day at Deniliquin from July to November: Maintain water quality within channels and pools. Reduce the frequency and magnitude of blackwater events, by preventing the accumulation of litter in channel and on bars and benches. Prevent stratification in shallow pools and provide sufficient water to dilute any water quality impacts associated with breaking stratification of deep pools. Maintain inundation of wetlands connected at pool level to minimise exposure of ASS.	Minimum of 1,500 ML/day at Deniliquin in July, increasing to 4,000 ML/day by mid August through to end November: Maintain water quality within channels and pools. Reduce the frequency and magnitude of blackwater events, by preventing the accumulation of litter in channel and on bars and benches. Prevent stratification in shallow pools and provide sufficient water to dilute any water quality impacts associated with breaking stratification of deep pools. Maintain inundation of wetlands connected at pool level to minimise exposure of ASS. Reconnect refuge holes.
	Pulse flow of 2,000 ML/day for 15–30 days in September/October and November – Promote productivity to maintain food webs and ecosystem function for in-channel flora and fauna. Maintain connectivity between main channel and billabongs and backwaters.	Two pulse flows averaging 3,000 ML/day at Deniliquin for 15–30 days in September/October and November (noting that this will encompass a rise, a period of flow maintenance and a managed recession) – Promote productivity to maintain food webs and ecosystem function for in-channel flora and fauna. Maintain connectivity between main channel and billabongs and backwaters.	Two pulse flows averaging 3,000 ML/day for 15–30 days one in September/October and the other in November / December – Promote productivity to maintain food webs and ecosystem function for in-channel flora and fauna. Maintain connectivity between main channel and billabongs and backwaters.	Two pulse flows peaking at 10,000 ML/day for 15–30 days in September/October and again November / December – Promote productivity to maintain food webs and ecosystem function for in-channel flora and fauna. Maintain connectivity between main channel and billabongs and backwaters.
	Augment flows when necessary to ensure rate of fall does not exceed 15 cm / day – Provide fish passage and allow biota to complete flow driven critical life cycle processes such as spawning, seed setting and dormant stages.	Augment flows when necessary to ensure rate of fall does not exceed 15 cm / day – Provide fish passage and allow biota to complete flow driven critical life cycle processes such as spawning, seed setting and dormant stages.	Augment flows when necessary to ensure rate of fall does not exceed 15 cm / day – Provide fish passage and allow biota to complete flow driven critical life cycle processes such as spawning, seed setting and dormant stages.	Augment flows when necessary to ensure rate of fall does not exceed 15 cm / day – Provide fish passage and allow biota to complete flow driven critical life cycle processes such as spawning, seed setting and dormant stages.

	Management objectives for specific water availability scenarios			
	Extreme dry Goal: Avoid damage to key ecological assets	**Dry** Goal: Ensure ecological capacity for recovery	**Median** Goal: Maintain ecological health and resilience	**Wet** Goal: Improve and extend healthy aquatic ecosystems
Water availability	Minimum allocation on record	30^{th} percentile year	50^{th} percentile year	70^{th} percentile year
Reed Bed Creek Wetlands – Werai Forest				
	None	None	5,000 ML/day for 15 days in two pulse flows to supplement a peak in September to October and a second peak in October to November – Maintain extent and health of reed bed vegetation. Maintain connectivity between river channel and low lying wetlands for fish and other aquatic fauna between pulses. Promote successful breeding of waterbirds with short breeding cycles (e.g. ducks and coots). Augment flows when necessary to ensure rate of fall does not exceed 15 cm / day – Provide fish passage and allow biota to complete flow driven critical life cycle processes such as spawning, seed setting and dormant stages.	5,000 ML/day for 120 days from July to December to supplement "natural" peaks during wet conditions – Promote successful breeding of colonial nesting waterbirds. Augment flows when necessary to ensure rate of fall does not exceed 15 cm / day – Provide fish passage and allow biota to complete flow driven critical life cycle processes such as spawning, seed setting and dormant stages. *Note: May not be required if significant inundation has occurred in the previous water year.*

	Management objectives for specific water availability scenarios			
	Extreme dry Goal: Avoid damage to key ecological assets	**Dry** Goal: Ensure ecological capacity for recovery	**Median** Goal: Maintain ecological health and resilience	**Wet** Goal: Improve and extend healthy aquatic ecosystems
Water availability	Minimum allocation on record	30th percentile year	50th percentile year	70th percentile year
River red gum forests (including Werai Forest; Niemur Forest)				
	None	None	None	18,000 ML/day for 10 days to supplement a peak in September to October and a second peak in October to November – Maintain health of river red gum forests and woodlands. Promote productivity to maintain food webs and ecosystem function for in-channel flora and fauna. Maintain connectivity between main channel and floodplain. *Note: May not be required if significant inundation has occurred in the previous water year.*
Black Box woodland / Ephemeral wetlands and watercourses (includes Cockran Creek, Yarrien Creek and Poon Boon Lakes).				
	None	None	None	30,000 ML/day for 21 days to supplement a peak any time between June and December Maintain health of Black Box woodlands, and ephemeral creeks and watercourses. *Note: May not be required if significant inundation has occurred in the recent past. Will be assessed based on inundation history and future ecological requirements.*

In addition to the targets and events described by the MDBA (2010) there is some evidence to suggest that pulse flows, rather than constant flow conditions, may provide better outcomes with respect to fish recruitment (Watts et al. 2009). Collaborative research between the Murray Catchment Management Authority (MCMA), the Department of Sustainability, Environment, Water, Population and Communities (SEWPAC) and Charles Sturt University is investigating the effects pulse flows have on the Edward-Wakool system. Although research into the effects of pulse flows on native fish in Australia is in its infancy, it is thought that even small (in channel) pulse flows can trigger movement of large and small bodied native fish into breeding habitats. Pulse flows also affect food webs, with the first pulse in spring thought to prime large bodied fish for reproduction by stimulating productivity and providing ample food resources. The second pulse then provides the cue for spawning (King et al. 2008; Lyon et al. 2010). Therefore a series of two pulsed flows timed to match seasonal production and breeding requirements may provide the best outcomes for native fish.

There are also some specific water requirements that have been identified to ensure that water quality is maintained and to minimise impacts to fish and other aquatic fauna from increased salinity and temperature; and low dissolved oxygen and pH (Watkins et al. 2010). Principles that have been incorporated into the objectives are:

- Inundation of channels and benches during cooler weather, so that carbon inputs (from leaf litter) can be assimilated into the system and stimulate productivity;
- Avoiding very low flows during peak litter fall (summer), when high carbon concentrations combined with warmer weather (higher temperatures) can lead to blackwater events (Watkins et al. 2010);
- Moderate flows over spring and summer to prevent stratification in shallow pools (e.g. Wakool and Niemur Rivers and Merran Creek);
- Use of operational flows as a means to dilute water returning from floodplains to mitigate the effects of blackwater; and
- Use of operational flows to prevent drying and exposure of acid sulphate soils in wetlands connected at pool level.

Due to substantial knowledge gaps associated with this system, flows provided in Table 3 should be considered indicative only. As more information and knowledge is gained through research and monitoring of flow events, these objectives should be refined to provide more specific details such as target flows at various stages along the system and managed rise and recessions, rather than averages.

Table 3: Nesting habitat and inundation requirements for some species of wetland bird previously recorded breeding in the system (Webster 2008; Briggs 1990; Jaensch 2002).

Species[1]	Stimuli for breeding[2]	Nesting Habitat[3]	Inundation requirements[3]
Little pied cormorant (*Microcarbo melanoleucos*)	Flooding / seasonal	In forks and branches of trees (*Eucalyptus*) and tall shrubs in or over water; sometimes over dry land or on artificial structures.	Minimum depth of 30 to 50 centimetres for sufficient time to prevent nest site becoming dry before nestlings leave nest and reach maturity – three to four months.
White-necked heron (*Ardea pacifica*)	Flooding / seasonal	Low near-horizontal branch of tree in or overhanging water Trees (such as river red gum) fringing river channels, waterholes, lakes and ponds; wooded swamps (such as black box).	Minimum depth of 30 to 50 centimetres for sufficient time to prevent nest site becoming dry before nestlings leave nest and reach maturity – three months.
Great egret (*Ardea modesta*)	Flooding / seasonal	Wooded swamp (such as *Eucalyptus*); high in a tree or tall shrub standing in water, often at a higher site than associated species; on top of lignum shrub; sometimes high in trees on dry land.	Minimum depth of 30 to 50 centimetres for sufficient time to prevent nest site becoming dry before nestlings leave nest and reach maturity – three to four months.
Intermediate egret (*Ardea intermedia*)	Flooding / seasonal	Wooded swamp (such as *Eucalyptus*); high (pp to 15 metres above water) in a tree or tall shrub standing in water.	Minimum depth of 30 to 50 centimetres for sufficient time to prevent nest site becoming dry before nestlings leave nest and reach maturity – three to four months.
Nankeen night heron (*Nycticorax caledonicus*)	Flooding	Wooded swamp (such as *Eucalyptus*); in a tree or tall shrub standing in water, at variable height; often in a discrete zone (encircling a group of breeding egrets); sometimes high in trees on dry land.	Minimum depth of 30 to 50 centimetres for sufficient time to prevent nest site becoming dry before nestlings leave nest and reach maturity – two to three months.
Glossy ibis (*Plegadis falcinellus*)	Flooding	Shrubby swamp (such as. lignum), wooded swamp (such as *Eucalyptus*), and reed/cumbungi beds. In a tree or tall shrub standing in water, usually low in the tree/shrub.	Minimum depth of 30 to 50 centimetres for sufficient time to prevent nest site becoming dry before nestlings leave nest and reach maturity – two to three months.
Australian white ibis (*Threskiornis molucca*)	Flooding / seasonal	Wide variety of habitats used for breeding: typically wooded swamp (such as. *Eucalyptus*), shrub swamp (such as lignum) and reed/cumbungi beds; also exotic wetland and dryland tree copses, bare islands and artificial structures.	Minimum depth of 30 to 50 centimetres for sufficient time to prevent nest site becoming dry before nestlings leave nest and reach maturity – ten weeks to three months (not relevant to nests on dry land).

PART 2:
Water Use Strategy

4. Environmental water requirements

4.1 Baseline flow characteristics

The daily flows anticipated in each month under various climate conditions are presented for the Edward River at Deniliquin (Table 4), Edward River downstream of Stevens Weir (Table 5), the Edward River at Liewah (Table 6) and the Wakool River at Stoney Crossing (Table 7). Deniliquin is the location where environmental flow objectives have been specified in Chapter 2 of this document, whilst Liewah and Stoney Crossing represent end of system flows. Downstream of Stevens Weir is a key location for river operations and delivery to the lower Edward River. This information is sourced from the MSM-Bigmod model of the River Murray system with The Living Murray (TLM) deliveries in place (run #20507), which provides a suitable baseline from which to assess environmental water demand shortfalls. These tables indicate that flow always occurs at Deniliquin, with clear peaks in dry and very dry years during the irrigation season. Flows downstream of Stevens Weir are lower than at Deniliquin because of flows and deliveries to the creeks and canals between the two locations. Flows at Liewah are more variable seasonally and have lower spring flow in wet years than upstream at Deniliquin.

Table 4: Streamflows (ML/d) for the Edward River at Deniliquin (1895–2009)

Month	Very dry year (minimum on record)	Dry year (30th percentile daily flow)	Median year (50th percentile daily flow)	Wet year (70th percentile daily flow)
Jul	44	776	1,534	3,089
Aug	279	1,799	2,860	5,561
Sep	666	2,161	3,717	7,106
Oct	738	2,827	3,970	6,796
Nov	684	2,484	4,075	5,330
Dec	855	2,634	3,279	3,986
Jan	685	2,528	3,145	3,988
Feb	1,363	2,308	3,185	3,805
Mar	636	2,196	2,746	3,772
Apr	348	1,666	1,924	2,173
May	143	894	1,179	1,540
Jun	90	431	634	1,297

Table 5: Streamflows (ML/d) for the Edward River d/s Stevens Weir (1895–2009)

Month	Very dry year (minimum on record)	Dry year (30th percentile daily flow)	Median year (50th percentile daily flow)	Wet year (70th percentile daily flow)
Jul	100	724	1,484	3,002
Aug	100	675	1,954	4,904
Sep	100	799	2457	5,679
Oct	130	599	2,024	4,419
Nov	100	918	2,505	3,814
Dec	100	538	1,226	2,062
Jan	100	314	1,021	1,912
Feb	100	499	1,418	2,038
Mar	145	490	1,307	1,980
Apr	100	411	703	1,155
May	100	400	719	1,097
Jun	100	410	623	1,276

Table 6: Streamflows (ML/d) for the Edward River at Liewah (1895–2009)

Month	Very dry year (minimum on record)	Dry year (30th percentile daily flow)	Median year (50th percentile daily flow)	Wet year (70th percentile daily flow)
Jul	224	911	1,596	2,694
Aug	126	1,116	2,313	4,304
Sep	53	1,244	2,950	5,167
Oct	32	854	2,180	4,117
Nov	108	1,106	2,097	3,116
Dec	3	901	1,675	2,295
Jan	99	769	1,267	1,726
Feb	107	807	1,408	1,878
Mar	131	693	1,333	1,765
Apr	37	594	990	1,433
May	93	646	906	1,194
Jun	217	677	926	1,581

Table 7: Streamflows (ML/d) for the Wakool River at Stoney Crossing (1895–2009)

Month	Very dry year (minimum on record)	Dry year (30th percentile daily flow)	Median year (50th percentile daily flow)	Wet year (70th percentile daily flow)
Jul	64	77	106	716
Aug	66	200	536	3,428
Sep	334	504	1,548	5,824
Oct	352	477	1,160	5,028
Nov	302	422	957	2,220
Dec	282	369	625	1,101
Jan	286	342	405	556
Feb	291	338	403	607
Mar	311	382	448	592
Apr	329	419	446	526
May	290	382	395	419
Jun	126	203	256	315

The relationship between the River Murray downstream of Yarrawonga Weir and the Edward River at Deniliquin requires consideration when planning releases of environmental water from Hume Dam.

Figure 4 illustrates the estimated relationship between the River Murray downstream of Yarrawonga Weir and the Edward River at Deniliquin, based on modelled flows from MSM-Bigmod (run #20507 from 1895–2009 for flows in the River Murray less than 100,000 ML/d). Modelled data was used because the recorded flows at Deniliquin contained significant amounts of missing data in the historical record. Figure 4 shows that the proportion of River Murray water that flows through the Edward River at Deniliquin increases with increasing flow. At the target Deniliquin flows of 18,000 ML/d on average, 38 per cent of River Murray flows are estimated to reach Deniliquin, whilst at the target flow of 30,000 ML/d on average, 50 per cent of River Murray flows are estimated to reach Deniliquin. The flows at Deniliquin have been adjusted for nine days travel time from downstream of Yarrawonga, however this may vary depending on flow rate. For example, travel time is about seven or eight days under regulated conditions and can increase to 12 days during flood conditions.

It should be noted that there is a high degree of uncertainty around these average values. The uncertainty in the relationship at low flows (i.e. less than 15,000 ML/d) is partly due to differences in operation of the Millewa Forest regulators from year to year. When the regulators are open, they can provide flow to the Edward River at River Murray flows between 3,500–6,000 ML/d, but when they are closed they do not commence to flow until the River Murray exceeds 10,500 ML/d. Other sources of uncertainty in the relationship between the River Murray and Edward River flows include:

- differences from year to year in the antecedent conditions in the Millewa Forest and effluent creeks downstream of Yarrawonga;
- streamflow gauging uncertainty;
- differences in the volume of water released through the escapes;
- differences in travel time on rising and falling limbs of flood hydrographs; and
- the influence of backwater effects from the Goulburn River under high flow conditions.

Further information on individual flood peak behaviour is discussed in Section 6.

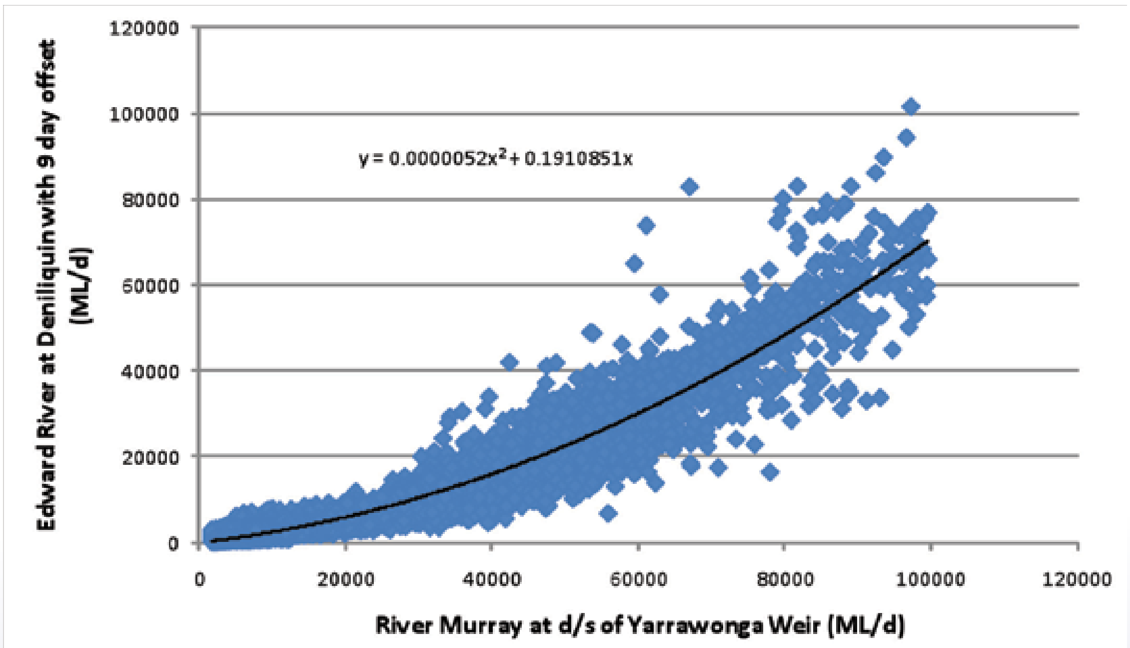

Figure 4: Modelled relationship between flows in the River Murray and Edward River for River Murray flows <100,000 ML/d

4.2 Environmental water demands

In Section 2, there are separate flow targets specified for the permanent, semi-permanent regulated rivers and creeks, the Reed Bed Creek wetlands and the river red gum forests. Each of these flow targets is different in different climate years. The volume required to deliver each event will depend on the antecedent conditions in the river and the ability to enhance a natural flood event.

The frequency of the desired pulse flows under current river system operation was estimated using data extracted from the MSM-Bigmod model with The Living Murray water deliveries already in place (run #22051). This establishes baseline conditions after delivery of The Living Murray environmental flows. The results of this analysis are shown in Table 8, which indicates that an event of 18,000 ML/d occurs in September/October on average in three years out of every 10 years and that most of these events (2.3 years in 10) are of the desired duration of 10 days. This means that the desired 18,000 ML/d event is likely to occur already in most wet years, but is not likely to occur in median to very dry years.

Table 8: Average recurrence interval for desired pulse flows for Edward River at Deniliquin, 1895–20

Climate Year	Event	No. of years in 10 with event of any duration	No. of years in 10 with event of specified duration	Max. interval between events of specified duration (years)
Very Dry	1,500 ML/day, 15 Aug – 30 Nov	9.9	5.8	5
	2,000 ML/day for 15 days, Sep/Oct	9.8	9.6	3
	2,000 ML/day for 15 days, Nov	9.6	8.6	3
Dry	1,500 ML/day, 1 Jul – 30 Nov	10.0	2.6	9
	3,000 ML/day for 30 days, Sep/Oct	9.1	4.8	5
	3,000 ML/day for 30 days, Nov	8.1	4.2	6
Median	1,500 ML/day, 1 Jul – 30 Nov	10.0	2.6	9
	3,000 ML/day for 30 days, Sep/Oct	9.1	4.8	5
	3,000 ML/day for 30 days, Nov	8.1	4.2	6
	5,000 ML/day for 15 days, Sep/Oct	6.7	5.0	7
	5,000 ML/day for 15 days, Nov	6.3	4.9	10
Wet	1,500 ML/day from 1 Jul increasing to 4,000 ML/d from 15 Aug – 30 Nov	9.1	0.6	35
	10,000 ML/day for 2 days, Sep/Oct	3.9	3.8	11
	10,000 ML/day for 2 days, Nov/Dec	2.3	2.3	11
	5,000 ML/day for 120 days, Jul–Dec	8.0	1.6	21
	18,000 ML/day for 10 days, Sep/Oct	3.0	2.3	13
	18,000 ML/day for 10 days, Oct/Nov	2.4	2.0	14
	30,000 ML/day for 21 days, Jun–Dec	2.5	1.1	23

The estimated range of volume requirements is shown in Table 9 for each desired event. The triggers for implementing each flow recommendation in this analysis are in line with the operational triggers outlined subsequently in Section 5. Hydrologic analysis is based on static output from MSM-Bigmod. Greater flexibility in delivery rules and improved understanding of the volumes requiring delivery may be possible if these rules are investigated using MSM-Bigmod interactively.

The values in Table 9 represent the potential additional volume to be delivered at Deniliquin and the equivalent volume in the River Murray downstream of Yarrawonga to meet the required event duration above the specified flow threshold. These volumes are in addition to any water delivered under The Living Murray program. The relationship in Figure 4 has been used to convert shortfalls at Deniliquin to an equivalent shortfall at Yarrawonga. This calculation assumes that for River Murray flows less than 10,500 ML/d (maximum regulated flow through the choke) environmental water can be delivered to the Edward River without significant loss, using spare channel capacity in the Edward River, Gulpa Creek and the Murray Irrigation Limited escapes (subject to MIL approval). This spare capacity may not always be available, as discussed in Section 5 on operational delivery constraints, in which case the volume required could be significantly higher.

The volume of water required increases as the climate becomes wetter. For a very dry year, an average of 12,900 ML in the River Murray at downstream of Yarrawonga would be required to maintain winter/spring baseflows and provide the two small fresh events, with the majority of this water (10,000 ML) required for the provision of the baseflows. In a wet year an average of 435,000 ML would be required at downstream of Yarrawonga to provide all of the targeted wet year events. The 5,000 ML/d baseflow creates the largest demand for water in a wet year on average, although the 30,000 ML/d pulse flow creates the largest maximum annual demand. The development of triggers to cease delivering these high flow events could significantly reduce the volumes of water required, particularly when flows are above the operational trigger to commence the event for only a short duration.

It is assumed for the pulses equal to or above 10,000 ML/d that additional water is only required if flows exceed the desired flow threshold under baseline flow conditions. For the 10,000 ML/d event, which is only of one or two days duration, it is assumed that environmental water would be used to increase the flood peak for events near this target volume. For the events equal to and above 10,000 ML/d, which are of longer duration, it is assumed that environmental water would only be used to extend existing events to the desired duration. This is because the desired frequency of events of any duration above the target threshold is already met for recommended median and wet year events above 10,000 ML/d, but the desired duration is not always met at the desired frequency, as shown in Table 8. A falling limb has been added to the environmental water demand hydrographs for the pulses equal to or above 10,000 ML/d. The rate of fall is assumed to be 5 per cent per day for flows above 18,000 ML/d and 10 per cent per day for flows below 18,000 ML/d, based on the examination of falling limb hydrographs in the MSM-Bigmod data at Deniliquin. At these high flows, these rates of rise and fall are based on largely natural runoff events.

The required delivery volume may vary considerably from year to year depending on the ability to forecast flow conditions prior to deciding whether to proceed with the event. The volumes required for the pulse flows in Table 9 are therefore indicative only. Actual volumes required should be based, as best as possible, on MDBA operational model forecasts. For the analysis of the twin winter/spring pulse for Reed Bed Creek in median climate years, the second pulse was assumed to occur after a period of independence of not less than 15 days.

Table 9: Range of additional volumes to achieve desired environmental flows

Climate year	Event	No. of years in 10 event is triggered (across record period)	Volume provided at Deniliquin		Volume provided at Yarrawonga	
			Average volume provided in given climate years (GL/yr)	Maximum volume provided (GL/yr)	Average volume provided in given climate years (GL/yr)	Maximum volume provided (GL/yr)
Very Dry	1,500 ML/day, 15 Aug – 30 Nov	0.9	10.0	43.5	10.0	43.5
	2,000 ML/day for 15 days, Sep/Oct	0.4	0.6	7.5	0.6	7.5
	2,000 ML/day for 15 days, Nov	0.5	1.5	7.5	2.3	14.6
Dry	1,500 ML/day, 1 Jul – 30 Nov	1.8	13.7	38.0	14.0	38.7
	3,000 ML/day for 30 days, Sep/Oct	1.3	7.5	26.9	9.4	36.3
	3,000 ML/day for 30 days, Nov	1.2	9.4	32.9	16.3	79.2
Median	1,500 ML/day, 1 Jul – 30 Nov	1.7	17.4	49.3	17.8	49.3
	3,000 ML/day for 30 days, Sep/Oct	2.0	12.2	34.1	18.3	45.2
	3,000 ML/day for 30 days, Nov	1.9	15.5	36.9	27.5	73.2
	5,000 ML/day for 15 days, Sep/Oct	2.0	21.7	47.4	41.4	124.8
	5,000 ML/day for 15 days, Nov	2.2	16.0	30.0	36.0	97.5
Wet	1,500 ML/day from 1 Jul increasing to 4,000 ML/d from 15 Aug – 30 Nov	4.4	95.2	278.6	134.5	383.0
	10,000 ML/day for 2 days, Sep/Oct	1.1	3.5	25.5	8.3	57.3
	10,000 ML/day for 2 days, Nov/Dec	1.4	4.2	41.8	9.9	80.2
	5,000 ML/day for 120 days, Jul–Dec	3.5	57.1	166.5	121.4	385.4
	18,000 ML/day for 10 days, Sep/Oct	0.9	1.6	34.6	3.0	59.8
	18,000 ML/day for 10 days, Oct/Nov	0.8	2.3	66.1	4.9	152.0
	30,000 ML/day for 21 days, Jun–Dec	1.8	81.1	488.4	152.8	991.6

A summary of the maximum and annual volumes required averaged across all years is shown in Table 10. This table shows that on average 250 GL/yr would be required in the River Murray downstream of Yarrawonga to deliver the desired environmental flows.

Table 10: Range of additional volumes to achieve desired environmental flows across all climate years

Climate year	Deniliquin			d/s Yarrawonga		
	Maximum annual volume in given climate years (GL/yr)	Average annual volume in given climate years (GL/yr)	Average annual volume, averaged over all climate years (GL/yr)	Maximum annual volume in given climate years (GL/yr)	Average annual volume in given climate years (GL/yr)	Average annual volume, averaged over all climate years (GL/yr)
Very Dry	55.6	12.1	1.4	55.6	12.9	1.5
Dry	93.9	30.5	6.4	111.8	39.7	8.4
Median	124.6	82.8	15.3	294.7	141.1	26.0
Wet	662.2	245.1	120.4	1,124.5	434.8	213.6
All years	n/a	n/a	143.5	n/a	n/a	249.5

The effect of the proposed environmental flow recommendations on the average and maximum interval between events is shown in Table 11. This table shows, for example, that by using environmental water in the manner proposed, the frequency of years with flows above 3,000 ML/d for 30 days in November would increase from four years in 10 to occurring in all but very dry years (just under nine years in 10). The maximum interval between events is significantly reduced.

Table 11: Change in recurrence intervals under proposed watering regime

Climate year	Event	No. of years in 10 with event of the specified duration		Maximum interval between events (years)	
		Current	Proposed	Current	Proposed
Very Dry	1,500 ML/day, 15 Aug – 30 Nov	5.8	10.0	5	1
	2,000 ML/day for 15 days, Sep/Oct	9.6	9.9	3	1
	2,000 ML/day for 15 days, Nov	8.6	10.0	3	1
Dry	1,500 ML/day, 1 Jul – 30 Nov	2.6	8.9	9	4
	3,000 ML/day for 30 days, Sep/Oct	4.8	9.0	5	4
	3,000 ML/day for 30 days, Nov	4.2	8.8	6	4
Median	1,500 ML/day, 1 Jul – 30 Nov	2.6	8.9	9	4
	3,000 ML/day for 30 days, Sep/Oct	4.8	9.0	5	4
	3,000 ML/day for 30 days, Nov	4.2	8.8	6	4
	5,000 ML/day for 15 days, Sep/Oct	5.0	7.9	7	5
	5,000 ML/day for 15 days, Nov	4.9	7.8	10	8
Wet	1,500 ML/day from 1 Jul increasing to 4,000 ML/d from 15 Aug – 30 Nov	0.6	5.0	35	12
	10,000 ML/day for 30 days, Sep/Oct	3.8	4.7	11	10
	10,000 ML/day for 30 days, Nov/Dec	2.3	3.7	11	11
	5,000 ML/day for 120 days, Jul–Dec	1.6	5.0	21	12
	18,000 ML/day for 10 days, Sep/Oct	2.3	2.7	13	13
	18,000 ML/day for 10 days, Oct/Nov	2.0	2.5	14	14
	30,000 ML/day for 21 days, Jun–Dec	1.1	2.4	23	22

5. Operating regimes

5.1 Introduction

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

- Identifying the target environmental flow recommendations for the coming season;
- Defining triggers to commence and cease delivering those recommended flows;
- Defining triggers for opening or closing environmental flow regulators; and
- Identifying any constraints on water delivery, such as available airspace in irrigation channels, the potential for flooding of private land, delivery costs, limits on releases from flow regulating structures and interactions with other environmental assets.

5.2 Identifying target environmental flow recommendations

The selection of target environmental flows in each of the different climate years is triggered by the allocation in July, as shown in Table 12. For example, when the high security allocation in July is 100 per cent but the general security allocation is less than 20 per cent, then the recommendations assigned to the dry climate year would be targeted. Allocations have been used as a surrogate for anticipated flow conditions in the Edward River, because the differences in within channel flow in different climate years (previously presented in Table 4) are largely driven by the use of allocations for irrigation supply. If flow conditions change rapidly, such as in a major runoff event, consideration should be given to aiming for higher volume events associated with a wetter climate year. The selection of target flows should be flexible and in response to conditions in the Edward-Wakool and River Murray, because the flow thresholds for achieving ecological benefits aligned with each threshold, particularly for the higher flow events, are not precisely known at the current time.

For the recommendations associated with bird breeding and inundation of the river red gum forests and black box woodland / ephemeral wetlands, consideration should be given to the time since the last watering event. For example, if a bird breeding event has occurred naturally in the preceding summer period, then the flow recommendations associated with this event in the following winter/spring period may not be needed.

Table 12: Identifying seasonal target environmental flow recommendations

Climate year for selecting flow recommendations	NSW Murray High Security Allocation in July	NSW Murray General Security Allocation in July
Very dry	< 100%	0%
Dry	100%	1–20%
Median	100%	21–40%
Wet	100%	>40%

Using these triggers, the frequency of very dry years is approximately 1.1 years in 10, dry years occur approximately 2.1 years in 10, median years occur approximately 1.8 years in 10 and wet years occur 4.9 years in 10. The modelled frequency of wet years is higher than expected under natural conditions,and further adjustment of these triggers could be undertaken to better refine them. This data is based on using modelled allocations at the start of July, but allocations from mid July could be used if a start of July allocation is not announced.

5.3 Delivery triggers

Proposed operational triggers for delivering the environmental flow recommendations are presented in Table 13.

The delivery of the 1,500 ML/d baseflow in all years occurs continuously over the season specified in the flow recommendations and from the nominated start date. These flows are within channel and can be delivered through the Edward River and Gulpa Creek if not already being provided to meet critical human needs and irrigation demands.

Flow pulses are preferentially provided in response to naturally occurring flow events. The smaller pulses up to 3,000 ML/d are within channel and can be delivered through the Edward River, Gulpa Creek or MIL escapes if not already provided to meet irrigation demands. If these pulses do not occur naturally, a date is specified to trigger delivery within the season specified for the recommendation.

The ability to deliver the flow pulses of 5,000 ML/d are dependent on circumstances in the river system. For the short duration pulses of 15–30 days, they will often occur naturally. Where they do not occur naturally, this peak volume is beyond the channel capacity of the Edward River, Gulpa Creek and MIL escapes. The use of the escapes is dependent on available airspace and incurs additional charges, as explained later in this section. Delivery could be supplemented via the wetland regulators through the Millewa Forest. The use of the Millewa Forest regulators will involve high losses through the forest and would need to occur in harmony with the flow deliveries to the forest. The forest regulators would need to be open to minimise the volume required for delivery of water to the Edward River via this mechanism.

The delivery of the 10,000 ML/d pulse flow at Deniliquin is only of short duration, so where it occurs naturally there is no role to extend it through environmental water deliveries. The threshold for a 10,000 ML/d event at Deniliquin equates to a flow of approximately 29,700 ML/d in the River Murray downstream of Yarrawonga. A trigger for delivery has therefore been arbitrarily set below this value at 20,000 ML/d for environmental watering to increase smaller flood peaks to the desired peak. This watering event needs to occur in conjunction with a Barmah-Millewa Forest watering. Environmental water managers would need to rely on River Murray Operations forecasts of River Murray flow behaviour to estimate anticipated peak flows downstream of Yarrawonga in advance of the release.

Delivery of higher pulse flows (≥18,000 ML/d events at Deniliquin) is triggered by an equivalent flow in the River Murray downstream of Yarrawonga. The 18,000 ML/d event at Deniliquin is estimated to be triggered by a flow of 49,500 ML/d downstream of Yarrawonga and the 30,000 ML/d event at Deniliquin is triggered by a flow of 62,000 ML/d downstream of Yarrawonga. These events are largely unregulated, but can be enhanced by releasing environmental water from Hume Dam if it is not spilling, subject to downstream flooding constraints discussed later in this chapter.

Table 13: Summary of operational regime for achievement of environmental objectives

Climate year	Flow objective in Edward River at Deniliquin	Season/ timing	Average return period	Trigger for delivery	Trigger for ceasing delivery
Very dry	1,500 ML/d	15 Aug–30 Nov	All very dry years	Maintain throughout season	n/a
	2,000 ML/d for 15 days	Sep/Oct		Commence delivery if: -- Flow at Deniliquin > 2,000 ML/day; or -- By October 17 Whichever occurs earliest.	n/a
	2,000 ML/d for 15 days	Nov		Commence delivery if: -- Flow at Deniliquin > 2,000 ML/day; or -- By November 16th Whichever occurs earliest.	n/a
Dry	1,500 ML/d	1 Jul–30 Nov	All dry years	Maintain throughout season	n/a
	3,000 ML/d for 30 days	Sep/Oct		Commence delivery if: -- Flow at Deniliquin > 3,000 ML/day; or -- By October 2 Whichever occurs earliest.	n/a
	3,000 ML/d for 30 days	Nov		Commence delivery if: -- Flow at Deniliquin > 3,000 ML/day; or -- By November 1 Whichever occurs earliest.	n/a

Climate year	Flow objective in Edward River at Deniliquin	Season/ timing	Average return period	Trigger for delivery	Trigger for ceasing delivery
Median	1,500 ML/d	1 Jul–30 Nov	All median years	Maintain throughout season	n/a
	3,000 ML/d for 30 days	Sep/Oct		Commence delivery if: -- Flow at Deniliquin > 3,000 ML/ day; or -- By October 2 Whichever occurs earliest.	n/a
	3,000 ML/d for 30 days	Nov		Commence delivery if: -- Flow at Deniliquin > 3,000 ML/ day; or -- By November 1 Whichever occurs earliest.	n/a
	5,000 ML/d for 15 days	Sep/Oct		Commence delivery if: -- Flow at Deniliquin > 5,000 ML/ day; or -- By October 17 Whichever occurs earliest. Trigger flow at Deniliquin is ~20,000 ML/day in River Murray d/s Yarrawonga, depending on Millewa Forest regulator operation	n/a
	5,000 ML/d for 15 days	Nov		Commence delivery if: -- Flow at Deniliquin > 5,000 ML/ day; or -- By November 16 Whichever occurs earliest. Trigger flow at Deniliquin is ~20,000 ML/day in River Murray d/s Yarrawonga, depending on Millewa Forest regulator operation	n/a

Climate year	Flow objective in Edward River at Deniliquin	Season/ timing	Average return period	Trigger for delivery	Trigger for ceasing delivery
Wet	1,500 ML/d increasing to 4,000 ML/d by 15 August	1 Jul–30 Nov	All wet years	Maintain throughout season	n/a
	10,000 ML/d for 1–2 days	Sep/Oct		Commence delivery if: -- Flow downstream of Yarrawonga > ~20,000 ML/day; and -- Flow downstream of Yarrawonga is not expected to exceed 29,700 ML/d naturally.	n/a
	10,000 ML/d for 1-2 days	Nov/Dec		Commence delivery if: -- Flow downstream of Yarrawonga > ~20,000 ML/day; and -- Flow downstream of Yarrawonga is not expected to exceed 29,700 ML/d naturally.	n/a
	5,000 ML/d for 120 days	Jul–Dec		Commence delivery if: -- Flow at Deniliquin > 5,000 ML/ day; or -- By September 3rd; Whichever occurs earliest; and -- River Murray d/s Yarrawonga is expected to remain above ~20,000 ML/day for most of season.	Consider ceasing if Murray d/s Y'wonga flow will drop below ~20,000 ML/day for extended period without deliveries.
	18,000 ML/d for 10 days	Sep/Oct		Commence delivery if: -- Flow downstream of Yarrawonga > 49,500 ML/day	n/a
	18,000 ML/d for 10 days	Oct/Nov		Commence delivery if: -- Flow downstream of Yarrawonga > 49,500 ML/day	n/a
	30,000 ML/d for 21 days	Jun–Dec		Commence delivery if: -- Flow downstream of Yarrawonga > 62,000 ML/day	n/a

5.4 Delivery of water for high flow events

The environmental flow recommendations propose 10,000–30,000 ML/d events at Deniliquin in wet years and 5,000 ML/d events in median and wet years. The maximum regulated flow capacity of the combined Edward River and Gulpa Creek offtakes is 2,010 ML/d. However, during the 2010 flood event along the Murray (Figure 5) there was little change in the flow running through the Edward River and Gulpa Creek offtakes, even when the flow in the River Murray downstream of Yarrawonga was as high as 100,000 ML/d.

The flood peak observed in the Edward River at Toonalook, upstream of Deniliquin, is sourced from creeks flowing through the Millewa Forest and effluent creeks upstream of the Edward River offtake. These creeks include Native Dog Creek, Bullatale Creek and Tuppal Creek, amongst others. The commence to flow volumes for these creeks are approximately 3,500–10,500 ML/d for the forest creeks, 33,000 ML/d for Native Dog Creek, 50,000 ML/d for Bullatale Creek and 100,000 ML/d for Tuppal Creek (based on flow in the River Murray downstream of Yarrawonga) (SKM, 2006). Tuppal Creek and Bullatale Creek are continuously gauged for flow. In the 2010 event, Bullatale Creek appears to commence flowing at a much lower River Murray flow than indicated in SKM (2006); however the gauged flow contribution is much smaller than that from the other effluent creeks.

It can also be seen in Figure 5 that Tuppal Creek produces a flood peak after the flow downstream of Yarrawonga exceeds 100,000 ML/d and contributes to the flood peak at Toonalook. In later events in October and November 2010, Toonalook flow peaks three times, presumably due to the ungauged Millewa Forest flows and effluent creeks such as Native Dog Creek. This is because there is no increase in flow running through the Tuppal Creek or the Edward River and Gulpa Creek offtakes when there is a peak at Toonalook. Toupna Creek is the main creek running through the Millewa Forest and has a commence to flow threshold in the River Murray downstream of Yarrawonga of around 3,500 ML/d with the Mary Ada regulator open, and a regulated flow capacity of 2,800 ML/d. With the regulator closed, flows in the River Murray downstream of Yarrawonga must increase to around 10,500 ML/d for this creek to flow.

The modelled relationship between flows in the River Murray downstream of Yarrawonga and flows in the Edward River at Deniliquin, previously shown in Figure 4, indicate that the Edward River at Deniliquin is around 15–50 per cent of the flow at Yarrawonga. Delivery of high flow events is likely to be more efficient if the regulators in Millewa Forest are open; however at the target flows of 10,000–30,000 ML/d, it is likely that upstream effluent creeks will also flow. At the required flow volumes in the River Murray (approximately 27,000+ ML/d downstream of Yarrawonga), the Barmah Choke will have already exceeded bankfull capacity of 10,600 ML/d measured downstream of Yarrawonga. This means that the Edward River objectives for Reed Bed Creek Wetland and the River Red Gum Forests in median to wet years should be co-ordinated with flooding of the Barmah-Millewa Forest.

Some effluent creeks have been disconnected from the River Murray to protect Tocumwal and surrounding agricultural land from flooding. Better connectivity between the Edward River and the River Murray could be required to more efficiently deliver environmental flows; however this would require significant investigation and on-ground works. Options to improve connectivity between the River Murray and Tuppal Creek are being investigated by Murray CMA (2010) and include constructing a flow regulator through the levee bank and purchasing downstream flood easements.

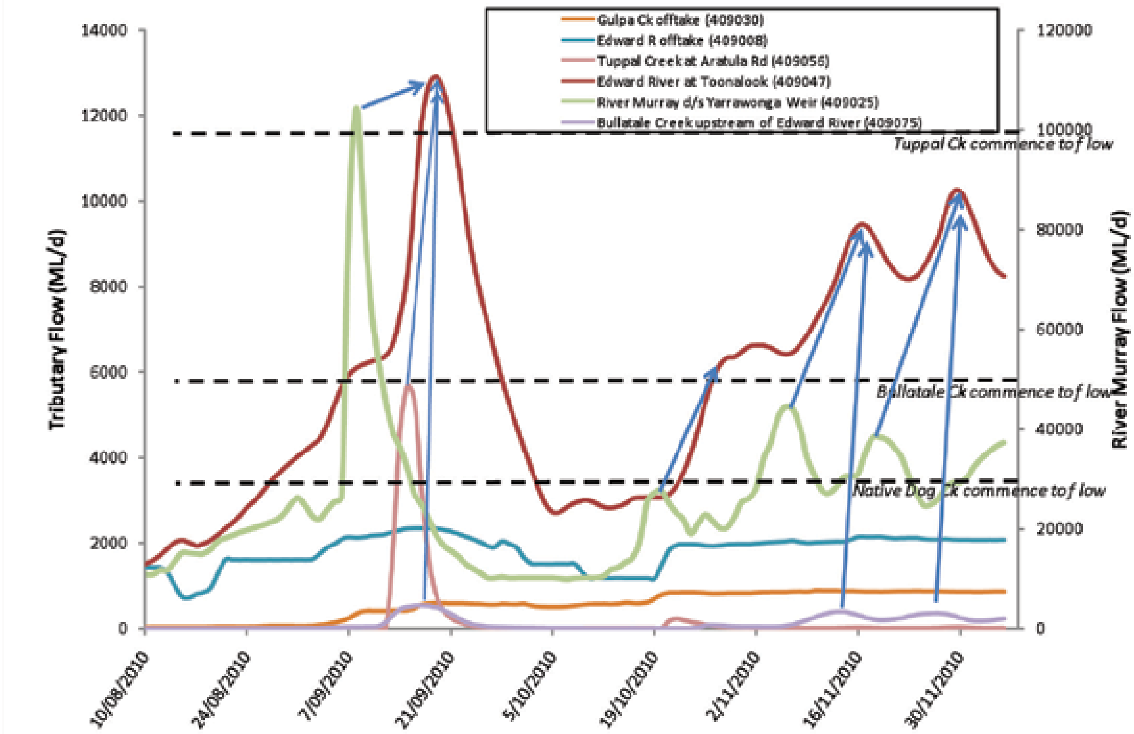

Figure 5: Sources of water during 2010 flood event

In the lower Wakool River, Waddy Creek (to lower Merran Creek) commences to flow at 2,000 ML/d in the Murray River at Barham. Little Merran Creek continued to flow when flow at Barham was only 1,400 ML/d in 2007, which indicates that the commence to flow for this creek is below this value. Both creeks have regulators and Murray River flows to Merran Creek from Waddy and Little Merran were stopped for a few months in 2007 by NSW to gain water savings. The regulated flow along Merran Creek typically ranges from 20–200 ML/d and the maximum regulated capacity at Franklings Bridge is 300 ML/d, above which the St Helena regulator and Erigin Creek Rock Weir are overtopped (MDBA 2010).

5.5 Distributing target Deniliquin flows to downstream rivers

The objectives summarised in Table 3 provide overall flow requirements for the Edward River at Deniliquin. As noted previously in Section 2, there are a number of requirements for water at locations downstream of Deniliquin that need to be adaptively managed by river operators, particularly in relation to water quality objectives. Considerations for water management downstream of Deniliquin have been presented below. This information has been compiled via an iterative process involving stakeholders such as SEWPaC, MDBA, Murray CMA, NSW Office of Water (NOW) and the Office of Environment and Heritage (OEH).

In a very dry year, the recommended minimum flow at Deniliquin is 1,500 ML/d from mid August to the end of November, with a pulse flow of 2,000 ML/d for 15 days in September/October and again in November. The irrigation delivery system may not be operating continuously. Operational factors to be considered in planning the use of environmental water include:

- Edward River flows are likely to be maintained by MDBA river operators, with a 250 ML/d target at Moulamein;
- Keeping Werai Forest regulators closed will improve water use efficiency;
- Wakool River is the last river to be cut off by the NSW Office of Water under low flow conditions. Environmental water could be used to maintain flows of 40 ML/d from August to April and 20 ML/d for the remainder of the year if not otherwise being provided. This should be provided in preference to additional flow along Colligen Creek / Niemur River and Merran Creek; and
- Colligen Creek / Niemur River are the first waterways to be cut off by the NSW Office of Water in conditions of low flow. In the event the NSW Office of Water indicates that they will be ceasing water delivery down the Colligen Creek / Niemur River for water delivery purposes, environmental water releases of 170 ML/d through Colligen Creek would help to prevent build up of organic material.

Key outcomes from the delivery of 30,000 ML of environmental, domestic and stock replenishment flows in the very dry year of 2007/08 are summarised in State Water (2008). The report highlights that if the delivery system has ceased, delivery loss can be minimised when the system is restarted if losses are shared between the environment and stock and domestic users. The notes also illustrate the potential for on-ground interference with flow regulating structures, such as digging trenches to reinstate flows or re-installing drop boards to create a weir pool. Some control sections for streamflow gauges in the Edward-Wakool system have been affected by sediment movement, so environmental water managers should check with the NSW Office of Water about the quality of data being collected in such an event prior to using it for accounting or delivery purposes.

In a dry year, the recommended minimum flow at Deniliquin is 1,500 ML/d from the start of July to the end of November with pulse flows of >3,000 ML/d for 30 days in September/October and again in November. The irrigation delivery system is likely to be operating continuously, but may not be at full capacity throughout the irrigation season. Operational factors to be considered in planning the use of environmental water include:

- Edward River flows are likely to be maintained by MDBA river operators;
- If not already being provided, environmental water could be used to maintain flow down Colligen Creek seven days after delivery of water to the forest, which is the estimated travel time through the forest. Water quality could be maintained by adjusting volume between 170 ML/d, which is the normal operating flow, and 800 ML/d, which is the flow at which water enters flood runners, potentially entraining additional organic material into the creek; and
- Environmental water could be used to maintain water quality in the Wakool River and Yallakool Creek. This could be sourced either from the Wakool River / Yallakool Creek or the Murray River via Merran Cutting or Waddy Creek.

In a median year, the recommended minimum flow at Deniliquin is 1,500 ML/d from the start of July to the end of November with pulse flows of 3,000 ML/d for 30 days in September/October and again in November, as well as 5,000 ML/d in two pulses of 15 day duration from September to November to maintain the Reed Bed Creek wetlands in the Werai forest. The irrigation delivery system is likely to be operating continuously and at full capacity in spring and summer. Operational factors to be considered in planning the use of environmental water include:

- Edward River flows are likely to be maintained by MDBA river operators. Augment flows to ensure rate of fall does not exceed 15 cm/day;
- Open Werai Forest regulators when flows above 3,000 ML/d are being provided based on natural ecological cues. If not already being provided, maintain flow down Colligen Creek seven days after delivery of water to the forest, which is the estimated travel time through the forest. Maintain water quality by adjusting volume above 170 ML/d, which is the normal operating flow, noting that at flows above 800 ML/d water enters flood runners. Flood peaks in excess of this volume may occur naturally during high flow events;
- Environmental water could be used to maintain water quality in the Wakool River and Yallakool Creek. This could be sourced either from the Wakool River / Yallakool Creek or the Murray River via Merran Cutting or Waddy Creek.Environmental water could be provided to ephemeral creeks such as Jimaringle, Cockran, Murrain and Yarrein Creeks; and

In a wet year, the recommended minimum peak flow at Deniliquin is 10,000 ML/d. At these flows Stevens Weir will be drowned out and there will be no capacity to re-direct flows down particular rivers. For the remainder of the year, operational factors to be considered in planning the use of environmental water include:

- Edward River flows likely to be maintained by MDBA river operators. Environmental water could be used ot augment flows to ensure rate of fall does not exceed 15 cm/day;
- If not already being provided, environmental water could be used to maintain flow down Colligen Creek seven days after delivery of water to the forest, which is the estimated travel time through the forest. Water quality could also be maintained by adjusting volume above 170 ML/d, which is the normal operating flow, noting that at flows above 800 ML/d water enters flood runners. Flood peaks in excess of this volume may occur naturally during high flow events;
- Environmental water could be used to maintain water quality in the Wakool River and Yallakool Creek. This could be sourced either from the Wakool River / Yallakool Creek or the Murray River via Merran Cutting or Waddy Creek; and
- Environmental water could be provided for ephemeral creeks such as Jimaringle, Cockran, Murrain and Yarrein Creeks.

5.6 Travel time

The ability to deliver water in response to natural flow events will be affected by the travel time through the system. Travel time information can be used to prepare for the opening and closing of wetland regulators in Werai Forest, for delivering dilution flows and for augmenting natural flow events. It will also affect the ability to co-ordinate deliveries between assets along the River Murray.

The travel time under regulated flow conditions from Hume Dam to Yarrawonga is approximately four days. Travel times through the Edward-Wakool system will vary with flow magnitude and flow route. For example, in the September 2010 runoff event the gauge on Tuppal Creek at Aratula Road peaked around seven days after the Yarrawonga peak. There was no noticeable flood peak at the Edward and Gulpa Creek offtakes, but the gauges at Toonalook, upstream of Deniliquin, and Stevens Weir, downstream of Deniliquin, peaked around 11–12 days after the Yarrawonga peak. The Edward River at Moulamein peaked around 23 days after the Yarrawonga peak, whilst the gauge at Liewah upstream of the River Murray peaked around 27 days after the Yarrawonga peak. That is, it took around 27 days for the flood event to pass through the Edward-Wakool system. Travel times will be longer if passing via the Wakool River and Yallakool Creek. A plot of this event is shown in Figure 6 and a summary of the travel times during this event is shown in Figure 7.

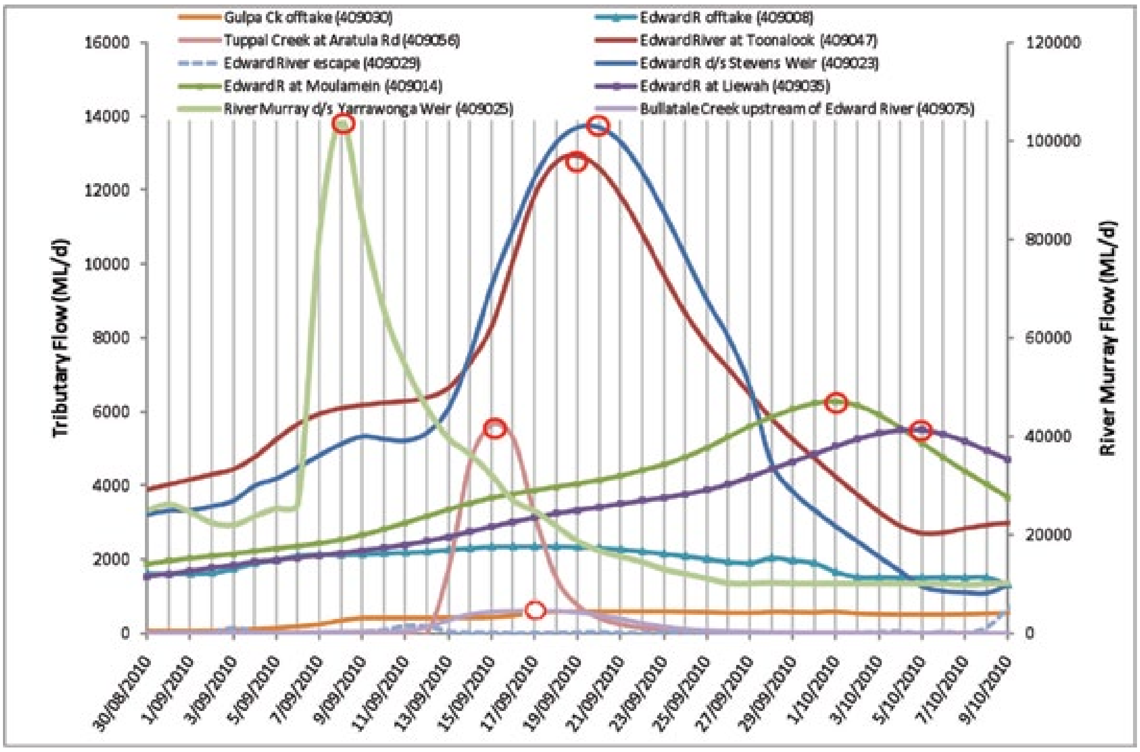

Figure 6: Hydrograph along the Edward River in flood event (Sep 2010)

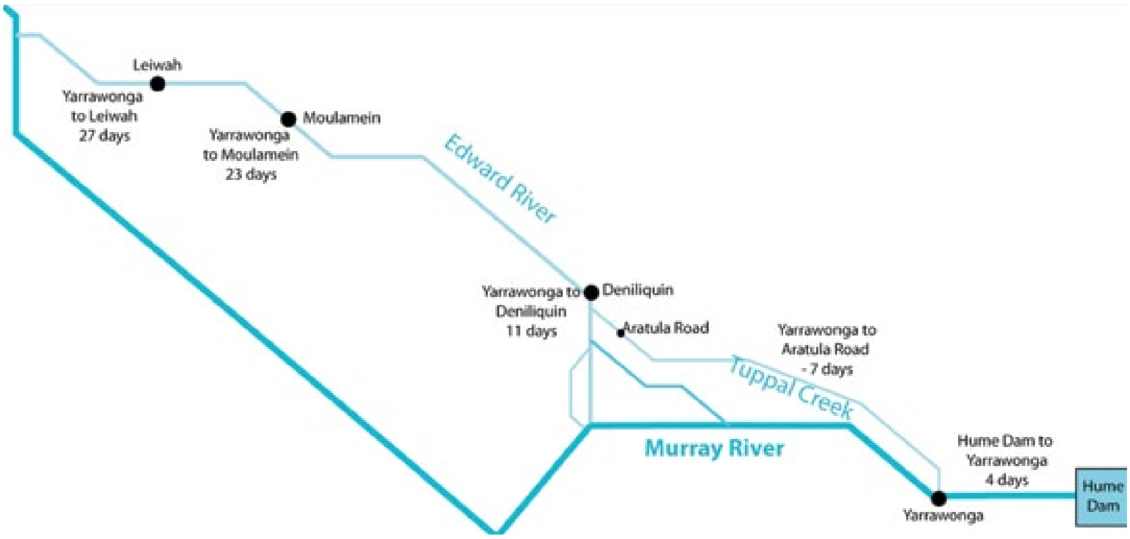

Figure 7: Travel time along the Edward River in flood event (Sep 2010)

5.7 Wetland regulators

There are regulators in place on Tumudgery Creek and Reed Bed Creek in the Werai Forest. The Tumudgery Creek regulator operated at a capacity of up to 120 ML/d in the 2009/10 watering. It temporarily operated at 160 ML/d due to erosion around the regulator which was since repaired. The 'commence to flow' for the Tumudgery Creek regulator (with the gates fully open) is a flow of about 800 ML/day in the Edward River. However, at this flow (or water level) the water only moves into the first few km of the creek and not into the forest. When the Edward River reaches a flow of about 2,100 ML/d (and the gates are open), water starts to flow into the forest. At flows of about 2,900 ML/d, water starts to overtop the regulator (MDBA, 2010). This regulator was built to prevent water entering the forest under regulated flow conditions; however the regulator can also be used to deliver regulated flow if required.

The Reed Bed Creek regulator operates at a capacity of up 90 ML/d, but regulated flow capacity was around 40 ML/d during the 2009/10 watering (MDBA 2010). The commence to flow threshold for the regulator was not available when preparing this report, so should be obtained from forest regulator operators.

5.8 Irrigation channel operation

There is the possibility of providing part of the environmental water for the lower flow recommendations (up to 5,000 ML/d) through the Edward River and Gulpa Creek offtakes, and through the Murray Irrigation channel escapes. Each of the escapes is drained at the end of the irrigation season, which may provide increased capacity for environmental water delivery. For example, in 2009 the volume of water drained from the escapes included 7,000 ML drained from the Edward Escape and under 2,000 ML from the Wakool, Yallakool, Perricoota and Finley Escapes (MDBA 2010). The capacity of various channel offtakes and escapes is listed in Table 14.

Table 14: Irrigation delivery capacities under regulated flows (MDBA 2010)

Location	Capacity (ML/d)
Edward River offtake	1,660
Gulpa Creek offtake	350
Gulpa Creek offtake when making deliveries to Reed Bed Swamp (Millewa forest)	750
Mulwala Canal offtake (from Yarrawonga Weir)	10,000
Edward Escape (from Mulwala Canal to Edward River)	2,400
Edward Escape (from Mulwala Canal to Edward River) during irrigation season to allow for rain rejections	2,100
Lawson's Siphon (Mulwala Canal under Edward River)	2,500
Wakool Canal	2,350
Wakool Escape (from Mulwala Canal to Wakool River)	500
Perricoota Escape (from Deniboota Canal to Torrumbarry Weir Pool)	200
Yallacoota Escape (from Mulwala Canal to Yallakool Creek)	80
Finley Escape (from Finley Channel to Billabong Creek)	250

The Murray Irrigation channel system is generally operated at full capacity in October to establish rice crops and again in February/March for winter pasture/rice maintenance, but does not operate at capacity in low allocation years (Green 2001). The movement of water entitlements out of the Edward-Wakool system may reduce the use of the channels in the future. During the irrigation season, the MIL system is also used by the MDBA to bypass the Barmah Choke through Mulwala Canal and the Edward River (via the Edward Escape).

The likelihood of spare capacity being available in the channel system for delivery of water through the escapes was examined using the MSM-Bigmod version with The Living Murray deliveries in place (run #20507). This version of the model provides the best readily available representation of conditions prior to the implementation of environmental flows. The minimum, maximum, median, 10^{th} and 90^{th} percentile channel capacities in each month of the year over the modelling period 1895–2009 are presented for each of the four climate conditions in Figure 8 for the Edward Escape. Edward Escape is by far the largest escape and the most likely to be able to deliver the required shortfall volumes to meet ecological objectives. The outcome from this analysis of Edward Escape is that:

- in a very dry year the channel system does not operate at full capacity and there was generally spare capacity during the winter/spring period in excess of 1,500 ML/d;
- in dry years, capacity was sometimes limited in summer/autumn, but capacity was generally available up to around 2,000 ML/d in winter/spring;
- in median years there was generally less than 1,000 ML/d available in the summer/autumn period and no capacity available in August at least 10 per cent of the time; and
- in wet years there was more channel capacity available early in the irrigation season than in median years, but available capacity was limited to less than 1,000 ML/d in summer most of the time. In some wet years the channels are operated at capacity to provide dilution flows during black water events, however this operational behaviour is not modelled in MSM-Bigmod and any flows delivered for this purpose would be in addition to those used to derive Figure 8. Spare capacity is also likely to exist in practice during periods of rainfall, when some irrigators do not take their ordered water.

All monthly statistics in Figure 8 are based on a minimum of 30 data points for each month.

A similar plot has been prepared for Mulwala Canal offtake in Appendix B. The data for Mulwala Canal offtake shows that in a very dry year there is likely to be spare capacity in the canal well in excess of the Edward Escape capacity. In dry to wet years the spare capacity in the canal decreases at the height of the irrigation season and in some years the spare capacity from November to March can be less than the Edward Escape capacity. This means that the offtake capacity of Mulwala Canal may occasionally be a constraint to using the Edward Escape to deliver environmental flows over these months, but will generally not be a constraint. Data for other escapes was not readily available from MSM-Bigmod.

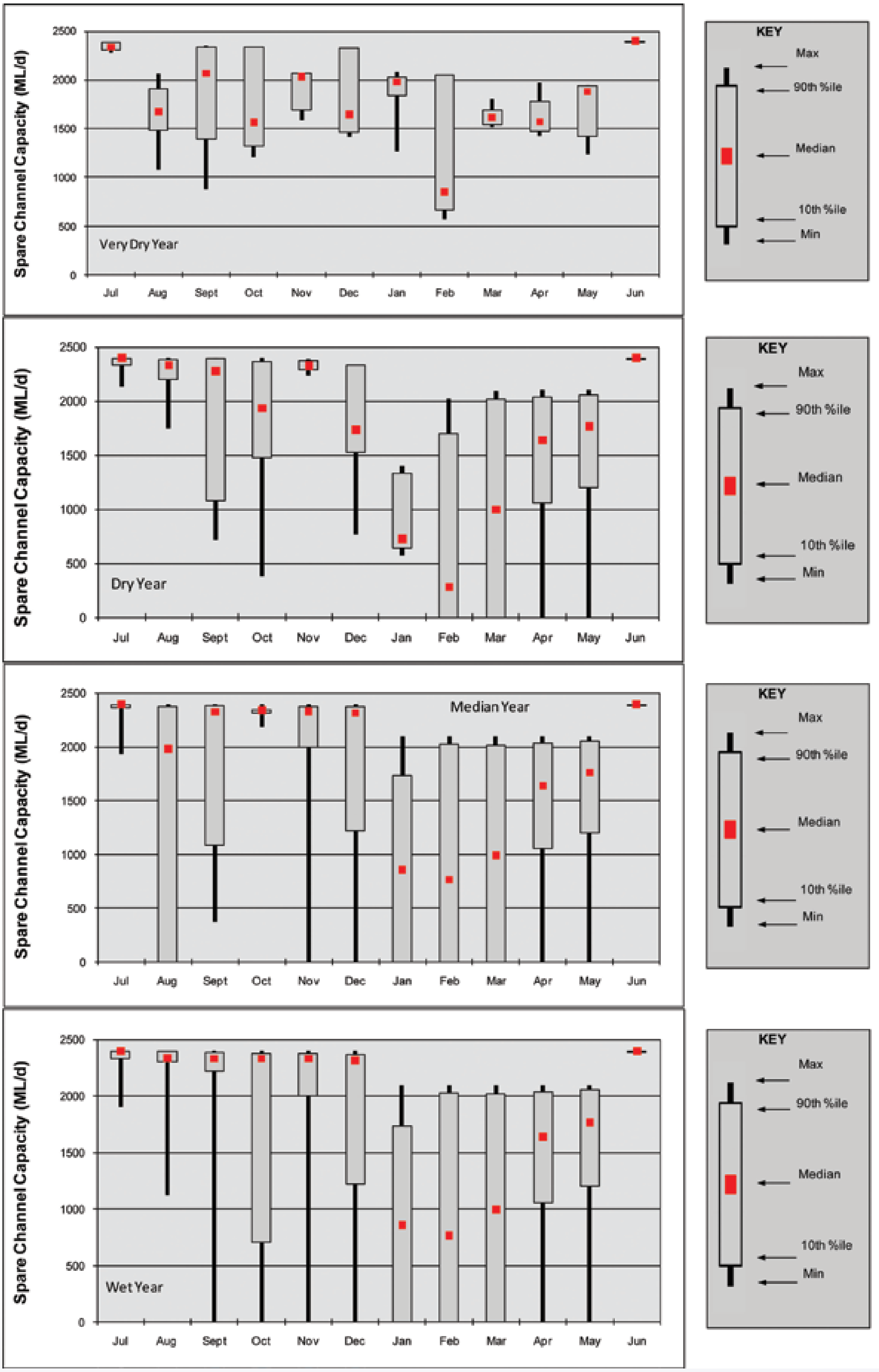

Figure 8: Spare channel capacity in Edward Escape, 1895–2009 (min, 10th percentile, median, 90th percentile and maximum daily values)

5.9 Flooding

Releases from Hume Dam are constrained to 25,000 ML/d (gauged at Doctors Point) under regulated flow conditions. Releases from the dam above this volume cause water levels to rise above flood easements and onto private property downstream of the dam. While releases above 25,000 ML/d are possible (and have been made historically), impacts to landholders require consideration. For example, damage to pasture grass generally occurs after inundation for five days or longer.

The River Murray channel has a capacity of 62,000 ML/d downstream of Yarrawonga Weir. Yarrawonga Weir is not expected to be a constraint on the delivery of environmental flows to the Edward-Wakool system.

Flooding in the Edward-Wakool system needs to be carefully managed at various points in the system under regulated flow conditions. The following issues require consideration in the delivery of large volumes of environmental water to the Edward-Wakool:

- The Edward River channel capacity downstream of Stevens Weir is 2,700 ML/d, above which water starts to flow over the top of the regulators (Junction regulator at the Niemur River) in the Werai Forest (MDBA 2010). This is not a constraint when intentionally delivering environmental flood flows.
- Colligen Creek is normally operated at 170 ML/d in summer. At above 800–850 ML/d water spills into lagoons and creek runners, which has been historically avoided to minimise losses when supplying regulated flow (MDBA 2010). Flows in excess of 500 ML/d can start to cause low level flooding in the low lying areas along the Niemur River downstream of Moulamein Road (Col Hood, State Water, pers.comm. March 2011).
- The Wakool River offtake from Stevens Weir operates at 150 ML/d, with the Wakool escape adding up to a further 500 ML/d. Low level road crossings are overtopped and some landholders might lose access when the Wakool River exceeds 200–300 ML/d (MDBA 2010).
- The Yallakool Creek offtake from Stevens Weir has a capacity of 600 ML/d, but low level road crossings are overtopped and some landholders might lose access at flows above 200 ML/d (MDBA 2010).
- The area downstream of the Yallakool Creek and Wakool River confluence known as Bookit Island can be subject to flooding. Farmers can lose access to roads into farms at around 500 ML/d and are unable to harvest crops when flows exceed around 1,000 ML/d (John Conallin, Murray CMA, pers.comm. March 2011). This figure will need to be confirmed with State Water.
- The regulated flow range of Merran Creek is 20–200 ML/d. The channel capacity at Franklings Bridge (upper end of Merran Ck) is 300 ML/d because at higher flows the St Helena regulator and Erigin Creek Rock Weir are overtopped (MDBA 2010).

5.10 Storage releases

The release capacity of Hume Dam is well in excess of the downstream constraints on releases due to flooding of private land. Current easements allow the passing of 25,000 ML/d along the reach between Hume Dam and Lake Mulwala. Releases above 25,000 ML/d have been made historically, including for the delivery of environmental flows, and were still well below the release capacity of the storage. The physical release capacity of Hume Dam is therefore not a constraint on delivery of water for the environment. Yarrawonga Weir is also not a constraint in delivering environmental flows downstream of the weir.

5.11 Weir flow control

Stevens Weir is not a constraint on the delivery of environmental flows. The weir can be operated to control low flows and can be removed during high flow events.

The Wakool River offtake from Edwards River (Stevens Weir pool) occurs at an elevation of 4.5 m, which is within the normal operating range for the weir pool under regulated flow of 4.5–5.2 m. Yallakool Creek commences to flow at an elevation of 3.5 m which is below the minimum operating level of Stevens Weir pool (MDBA 2010). Colligen Creek commences to flow at an elevation of 3.0 m and the Wakool River offtake commences to flow at an elevation of 4.0 m (Col Hood, State Water, pers.comm. March 2011).

Stevens Weir pool is drained annually, usually commencing from 1–15 May and re-instated from 1–15 July, depending on the end of MIL's irrigation season and the off-season works program. Small freshes are allowed to pass through as natural events when the weir pool is empty (Col Hood, State Water, pers.comm. March 2011).

5.12 Recreational users

Stevens Weir pool is used for recreation and the Edward River is used for recreational fishing, boating and kayaking along its length.

5.13 Water delivery costs

5.13.1 Delivery Costs

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

State Water also incurs charges for water delivered via the MIL escapes of $1.50/ML. Use of the MIL system incurs a water forfeit of 10 per cent on the water diverted at Yarrawonga Weir (based on the Memorandum of Understanding between MIL and NSW State Water).

Any water sourced from Victorian water shares for delivery to the Edward-Wakool system would first be transferred to a NSW Murray system account and then State Water's delivery costs would apply.

5.13.2 Regulated river water management charges

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

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

5.13.3 Carryover costs

State Water does not charge for carryover.

Goulburn-Murray Water charges per megalitre for water shares transferred from the spillable water account to an allocation bank account for the Murray system. The fee for transferring water from the spillable water account back to an allocation bank account is $3.25/ML for the Murray system. See http://www.g-mwater.com.au/customer-services/carryover#1 for more information.

5.14 Interactions with other assets

As discussed earlier in this section, the Edward-Wakool system is linked to the River Murray from Yarrawonga Weir to the Barmah-Millewa Forest. Delivering the desired flood flows in median and wet years to the Edward-Wakool system will also flood the Barmah-Millewa Forest. This is because the commence to flow for effluent creeks that can deliver major flood flows through the Edward-Wakool system are generally higher than the commence to flow for effluent creeks through the Barmah-Millewa Forests. Some flood runners through the Millewa Forests will contribute to the Edward River at flows as low as 5-10,000 ML/d in the River Murray downstream of Yarrawonga.

The Edward-Wakool system is linked to the Goulburn, Campaspe and Loddon Rivers via the effluent creeks in the River Murray from Barmah to Swan Hill, which feed into the lower Wakool system. Flows from these tributaries can supply the Lower Wakool River and the Merran Cutting. Similarly, water from the Koondrook-Perricoota Forest can interact with the lower Wakool River via effluent creeks near Barham and downstream ecological assets on the River Murray, such as the Lindsay, Mulcra and Walpolla Islands. Some of these effluent streams are permanently connected to the River Murray.

The Edward-Wakool system is connected to the lower Murray as the Wakool and Edward Rivers outfall downstream of Swan Hill. As such, flows from the Wakool and Edward Rivers may contribute to watering of downstream sites such as the Hattah Lakes and Lindsay-Wallpolla Islands.

6. Governance

6.1 Delivery partners, roles and responsibilities

The major strategic partners in delivering water to assets within the Edward-Wakool system include:

- OEH as the manager of the Adaptive Environmental Water in the Water Sharing Plan for the NSW Murray and Lower Darling Regulated Rivers Water Sources.
- MDBA as the operator of the Murray system releases from Hume Dam.
- SEWPaC as responsible for development and implementation of national policy, programs and legislation to protect and conserve Australia's environment and heritage.
- CEWH as responsible for management of water entitlements that the Commonwealth Government acquires to be used to protect or restore environmental assets.
- Murray Irrigation Limited and NSW State Water Corporation as operators of the Murray Irrigation channels and escapes.
- NSW State Water Corporation and NSW National Parks and Wildlife Service as operators of the flow regulators into and out of Werai Forest.
- Murray CMA as a stakeholder in the development and implementation of watering plans.
- Department of Sustainability and Environment (DSE) and OEH as holders of water for the Barmah-Millewa accounts.
- NSW Office of Water.

6.2 Approvals, licenses, legal and administrative issues

6.2.1 Water shepherding and return flows

Estimation of the volume of return flows in the 2009/10 watering of Werai Forest is documented in MDBA (2010). Manual gaugings were taken at the Tumudgery and Reed Bed Creek regulators. It was estimated that 4,700 ML was delivered through Tumudgery Creek regulator and 2,200 ML was returned for a net volume used of 2,500 ML. Reed Bed Creek wetlands received 2,600 ML less 1,800 ML return flow, which is a net of 800 ML. An additional 500 ML was assumed to cover higher "losses" in the Colligen-Niemur Rivers. However, the return flow arrangements for the 2009/10 watering events were 'one-off' arrangements. Return flow arrangements for future events may be based on modelled estimates of environmental use. Robust procedures for estimating return flows associated with the delivery of water to Werai Forest in 2010/11 are being developed by the Murray CMA and expected to be available in mid-2011 (John Conallin, Murray CMA, pers.comm. November 2010).

Section 45 of the Water Sharing Plan for the NSW Murray and Lower Darling Regulated Rivers Water Sources (currently suspended but scheduled to recommence from 1 July, 2011) allows water allocations to be re-credited in accordance with return flow rules established under Section 75 of the *Water Management Act 2000 (NSW)*. The process is to apply to the NSW Minister for Primary Industries for used water allocations to be re-credited to the licence. The return flow rules by which the application is to be assessed have not been formally established yet. Until such time as this policy is finalised, the process by which return flows could be granted would be for environmental water managers to apply to the NSW Minister for Primary Industries for the relevant licence to be re-credited.

Gaining credits in the River Murray downstream of the Edward River would again require an application to the NSW Minister for Water, which would allow any environmental water delivered to be reused to the end of the Water Sharing Plan area at the South Australian Border. Gaining credits at this location could require agreement of NSW, Victoria and South Australia.

Applications for credit of return flows is likely to be more successful if the application is received prior to the watering event and secondly if the watering event occurs under unregulated flow conditions, such as when supplementing a natural flood in the Edward-Wakool system. Under unregulated conditions there is less potential for reuse by consumptive users and therefore less potential for conflict over access to the returned water.

The existing operating rules for the River Murray system (contained in the accounting rules for "Edward System Losses") can create a disincentive for NSW (and River Murray Water) to operate the Edward-Wakool system for improved environmental outcomes. The existing rules penalise NSW for losses in the Wakool River rather than sharing losses between all jurisdictions, as is the case for flows passing through sections of the River Murray and Edward River that parallel the Wakool.

6.3 Trading rules and system accounting

6.3.1 Water trading

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

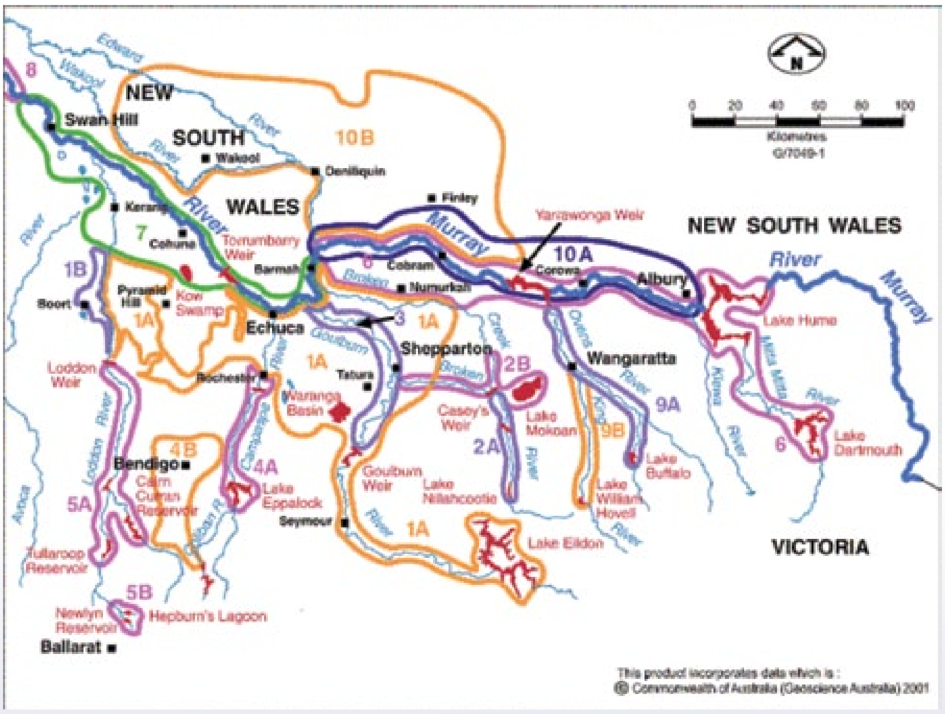

Figure 9: Trading zone boundaries (source: http://www.watermove.com.au)

The Edward-Wakool system is located in Trading Zone 10A (NSW Murray above Barmah). Water shares from this trading zone can be traded to all other zones in the southern connected Murray-Darling Basin, subject to the following constraints:

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

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

- Trade from Murray Irrigation Limited areas (zone 10B) receives a 10 per cent gain in share volume.
- Permanent trade is currently limited to four per cent per year from irrigation districts in Victoria. Goulburn-Murray Water advises via media release when these limits are reached for individual irrigation districts. There are various exemptions for this limit specified in the trading rules on the Victorian Water Register.

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

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

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

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

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

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

6.3.2 Water storage accounting

In the NSW Murray, water allocated against regulated river (high security) access licences and regulated river (conveyance) access licences cannot be carried over. For regulated river (general security) access licences in the Murray Water Source, up to 50 per cent may be carried over. These carry over rules are based on the Water Sharing Plan for the New South Wales Murray and Lower Darling Regulated Rivers Water Sources 2003, which has been suspended since 2006 due to on-going dry conditions but is scheduled to recommence from 1 July 2011 with the recent improvements in resource availability.

Water storage accounting for the Victorian Murray system is annual water accounting (July to June) with some carryover. Unlimited storage carryover is allowed, but water above 100 per cent of the water share volume can be quarantined in a spillable water account when there is risk of spill. Any carryover in the spillable water account cannot be accessed until the risk of spill has passed. If a spill occurs, carryover is the first to spill. Annual deduction for evaporation is five per cent of carried over volume. The fee for transferring water from the spillable water account back to the allocation bank account is $3.25/ML for the Murray system. See http://www.g-mwater.com.au/customer-services/carryover#1 for more informat

For more information on carryover, see http://www.g-mwater.com.au/customer-services/carryover/lbbcarryover/. DSE is currently reviewing these arrangements.

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

6.4 Water use plans

While there is no environmental flow determination or dedicated environmental water allocation plan for the Edward-Wakool system, it is identified as a hydrological indicator site by the MDBA (MDBA 2010a). In addition, there are two watering plans that include the Edward-Wakool system; Water Sharing Plan for the New South Wales Murray and Lower Darling Regulated Rivers Water Sources (DWE 2003) and Murray Adaptive Environmental Water Plan 2010–2011 (OEH 2010). These offer broad water objectives for the NSW Murray Catchment that are of relevance to the Edward-Wakool system (see section 2.1 above).

The environmental water provisions in the Water Sharing Plan for the New South Wales Murray and Lower Darling Regulated Rivers Water Sources 2003 (suspended in 2006 but scheduled to recommence from 1 July 2011) are implemented by the NSW OEH. The plan sets out provisions for planned environmental water (Barmah-Millewa Allowance, Barmah-Millewa Overdraw, Lower Darling Environmental Contingency Allowance, and a Murray Regulated River Water Source Additional Environmental Allowance and Adaptive Environmental Water). Of these, only the Murray Regulated River Water Source Additional Environmental Allowance and Adaptive Environmental Water are of relevance to Edward-Wakool system.

OEH intends to produce an Annual Watering Plan for each regulated water source in which they have a decision making role. This Watering Plan will cover the use of Environmental Water Allowances and any NSW licences nominated as Adaptive Environmental Water. The current plan covers the period 2010–2011 (OEH 2010). During the 2009–2010 season, the Murray Lower Darling Environmental Water Advisory Group (MLD EWAG) was established to provide advice on the management of environmental water within the NSW Murray Valley.

7. Risk assessment and mitigation strategies

Potential risks of delivering environmental water to the Edward-Wakool system have been assessed according to the SEWPaC risk assessment framework (see Appendix D) and are summarised in Table 15. The risk assessment provides an indication of the risks associated with the delivery of environmental water in the Edward-Wakool system. It should be noted that risks are not static and require continual assessment to be appropriately managed. Changes in conditions will affect the type of risks, the severity of their impacts and the mitigation strategies that are appropriate for use. As such, a risk assessment must be undertaken prior to the commencement of water delivery. Note that the risks quoted are the unmitigated risks, i.e. the risk from the event in the absence of adaptive management.

Conditions in the Edward-Wakool River in recent years have led to a number of serious impacts, particularly to the native fish community. If not managed properly, there is a risk to native fish from:

- Increased salinity (washed from the hypolimnion of deep pools when stratification breaks down);
- Increased acidity from wetting of previously exposed acid sulphate soils;
- Low dissolved oxygen (expanded on below);
- Fish stranding on the floodplain when water levels recede too rapidly;
- Lack of water – drying into series of pools; and
- Invasive species such as carp.

At low flows and cease to flow, salinity can increase in the Wakool, Niemur and Merran. This is managed by releasing fresher water in the Edward and trying to keep Murray flow high when a salinity spike from the Wakool is on its way to the Murray. State Water and/or the MDBA issue warnings to landholders along the Wakool if high salinities occur (MDBA 2010).

Low dissolved oxygen in the streams of the Edward-Wakool system can occur via a number of pathways. Releases of water from floodplain forests (Werai, Barmah-Millewa and Koondrook-Perricoota) can result in low dissolved oxygen blackwater events as organic matter on the floodplain surface is rapidly metabolised by microorganisms (Baldwin 2009; Gilligan et al. 2009). Build up of litter in channel and on benches is also sufficient to result in blackwater upon inundation, if not managed properly (Watkins et al. 2010). Investigations into acid sulphate sediments in wetlands along the Edward-Wakool system (Ward et al. 2010) have indicated high monosulphide concentrations in surface soils, which represent a high risk of deoxygenation after prolonged wet conditions. Rapid flows after a period of dry conditions can break stratification and release deoxygenated water from the bottom layers of deep in channel pools (Baldwin 2009).

The risk to native fish (and other aquatic fauna) from low dissolved oxygen may be mitigated by careful management to ensure sufficient flushing flows to prevent the build up of litter in channel and by timing water releases to occur at lower temperatures. Watkins et al. (2010) recommend continuous flows prior to and during times of peak litter fall (summer) to prevent the build-up of organic matter in channels. This continuous flow during warmer months would also prevent prolonged stratification in shallow waterholes.

Keeping sufficient flows in the Gulpa Creek and Edward River main channel, as well as keeping the Edward River escape open, will help to mitigate this.

Fish stranding on the floodplain and in billabongs and backwaters can be prevented by ensuring that water levels do not drop rapidly. This may mean the use of environmental water to moderate flood recessions and maintain rates of fall to less than 10-15 centimetres per day. This would also benefit other aquatic fauna and flora by providing time for egg-laying, seed setting and preparing other dormant life-cycle phases.

Environmental flows may also result in an increase in the abundance and diversity of invasive species within the system. Carp (*Cyprinus carpio*) are already present in the system, and experience from adjacent areas such as Barmah-Millewa has shown that floodplain inundation can favour carp spawning and recruitment (Stuart and Jones 2002). In addition, floodwaters can carry propagules for invasive plant species. Although this is a knowledge gap for this system, it is possible that native macrophytes could be displaced by invasive species such as arrowhead (*Sagittaria graminea*), which is known from the Edward River, and could be dispersed further through the system. However, the increased risk from environmental water delivery (above normal river operations) on the spread of invasive species is unknown. Weeds such as arrowhead, which require permanent water, may already be distributed through suitable habitat in the system and would not survive periods of dry, if transported into intermittent and ephemeral streams and wetlands.

Other potential risks are to waterbird breeding. Any inundation of large wetland areas (such as Reed Bed Creek in Werai Forest) can act as a stimulus for the onset of breeding. If inundation is of insufficient duration or water levels recede too rapidly, nests can be abandoned and breeding unsuccessful. This will require adaptive management to ensure that if a large scale breeding event commences, water is retained in wetlands and feeding areas long enough for successful fledging.

Table 15: Risk associated with water delivery in the Edward-Wakool system

Risk type	Description	Likelihood	Consequence	Risk level	Mitigation
Acid sulphate soils	Acid sulphate soils have been detected in wetlands along the Edward and Wakool Rivers. Although the risk of acidification from eight wetlands examined was low, there was a moderate risk of acidification from three wetlands (Ward et al. 2010). It should be noted that the risk of mobilisation of metals was low for all sites surveyed.	Likely	Minor	Medium	Ensure adequate flushing flows to dilute any potential effects of low pH water entering stream environments from inundated wetlands.
Salinity	Salt water can wash from the bottom of deep pools if stratification develops and then is broken by sudden high flows.	Likely	Minor	Medium	Continuous flows during summer months.
Invasive species	Carp breeding is likely to be favoured by large flow events in Werai State Forest.	Likely	Minor	Medium	Flow options for disruption of carp spawning can be investigated. However, any measures would need to maintain native fish spawning.
Blackwater	Blackwater events have been recorded with the release of water after prolonged dry or low flow periods. This can occur from in-channel litter build-up as well as floodwaters are returned to streams of floodplain surfaces.	Likely	Major to minor depending on event type, location and timing	High	Careful monitoring and adaptive management, particularly when waters are entering streams from floodplain surfaces. Can also be minimised by instigating floodplain inundation in cooler months. Manage flows in channel to prevent build up on in stream litter.
Water loss	Water may not reach intended target if (i) Millewa Forest regulators are closed or (ii) if Millewa Forest is dry prior to delivery of events or (iii) if escapes are to be used and consumptive users access the water.	Unlikely	Minor	Low	Communicate with OEH and MIL prior to delivery of water to ensure appropriate volumes are released for the current conditions.
Fish stranding	A rapid fall in water levels (as occurred this year) can lead to a loss of recruitment of both fish and waterbirds, with potentially significant effects to populations that are already stressed from drought.	Possible	Moderate	Medium	Manage flows to prevent rate of fall from exceeding 15 centimetres per day.
Unsuccessful recruitment of fish	Inappropriate delivery of pulses, or number of pulses, and management of flows after spawning lead to unsuccessful spawning, or death of recruits.	Possible	Moderate	Medium	Manage using expert knowledge on timing, magnitude, duration and rate of change for target fish species. Adaptively monitor during event, and after event.

Risk type	Description	Likelihood	Consequence	Risk level	Mitigation
Other considerations – unsuccessful bird breeding	Too short a duration of inundation of floodplain wetlands may result in a commencement of waterbird breeding and a subsequent abandoning of nests.	Possible	Moderate	Medium	Monitoring and adaptive management to maintain inundation should large scale waterbird breeding event commence.
Other considerations – drowning of floodplain vegetation	Floodplain inundation of too great a duration may result in the drowning of black box and potentially red gum trees.	Unlikely	Major	Medium	Ensure floodplain surfaces are not inundated for periods greater than 12 months.
Flooding of property	The duration of inundation of private property in the Edward-Wakool system may be lengthened when augmenting natural flood events in median and wet years.	Possible	Minor	Low	Work with other stakeholders to assess access risks in flood events and adjust watering accordingly.
Cutting off access	Some road access can be cut during flood events. Lengthening the duration of these events with Commonwealth water deliveries may lengthen the period for which certain roads cannot be used.	Possible	Minor	Low	Work with other stakeholders to assess access risks in flood events and adjust watering accordingly.
Infrastructure damage	Roads and other infrastructure may be damaged due to lengthened inundation from extension of flood events.	Unlikely	Minor	Low	Work with other stakeholders after watering events to assess any flood damage and adjust future watering accordingly.

8. Environmental Water Reserves

8.1 Environmental water holdings and provisions

8.1.1 Water planning responsibilities

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

The adaptive environmental water allocated under the water sharing plan is overseen by the NSW Office of Environment and Heritage (OEH). OEH is currently preparing an adaptive environmental water plan for the Murray Valley, which was available in draft form at the time of preparing this document (OEH 2010). During the 2009–2010 season, the Murray Lower Darling Environmental Water Advisory Group (MLD EWAG) was established to provide advice on the management of environmental water within the NSW Murray Valley. This includes representatives from the Murray CMA, and State Water and Australian Government observers.

8.1.2 Environmental water provisions

Minimum flows are not specified in the water sharing plan for the NSW Murray and Lower Darling Regulated Rivers Water Sources, rather a volume of water is allocated to the environment as part of the Adaptive Environmental Water allowance in the plan. The volume of the Adaptive Environmental Water allowance is listed in Section 8.1.3, Table 18 and is available for use across the NSW River Murray and Edward-Wakool areas. In addition to this, a Wakool System Allowance of 50,000–60,000 ML is provided as an additional volume by State Water to allow and account for delivery losses throughout the Wakool River, Yallakool Creek, Colligen Creek, Niemur River and Merran/Waddy Creeks. This allowance is not mentioned in the NSW Water Sharing Plan, however it has a long history of being implemented, and in 98 years in 100 is sufficient to provide minimum regulated flows through the Wakool system during the irrigation season.

Minimum flows are maintained along the Edward River and Gulpa Creek by River Murray Operations to maintain irrigation supply, stock and domestic supply, and to maintain water quality. This includes minimum flows during winter, listed in Table 16. In summer, operational flows are generally much higher than those specified in Table 16.

Table 16: Minimum Flow Maintained in the Edward River by River Murray Operations (MDBA 2010)

Location	Minimum Flow Maintained for Operations (ML/d)	Reason for Minimum Flow
Edward River offtake	100	for riparian and water quality requirements
Gulpa Creek offtake	80	for riparian and water quality requirements
Edward River at Stevens Weir	150	for riparian and water quality requirements
Edward River at Moulamein	250	to maintain access to stock and domestic supply offtakes

8.1.3 Current water holdings

Commonwealth environmental water holdings (as at October 2010) in the southern Murray-Darling connected system are summarised in Table 17. Licences have been identified separately upstream and downstream of the Barmah choke, as this can sometimes be a restriction on trade. The volume available upstream of the choke is up to approximately 194,000 ML, whilst licences below the choke can provide up to an additional 329,000 ML if traded to upstream of the choke. The volume of Commonwealth environmental water available in the Murray above the choke can be increased at any time by selling allocations tagged as sourced from elsewhere in the connected southern Murray-Darling Basin, and purchasing an equivalent volume in the Murray system upstream of the choke, subject to the trading rules described in Section 6.

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

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

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

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

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

Environmental water currently held in the River Murray upstream of the choke by other agencies is listed in Table 18. Only volumes upstream of the choke have been listed, as these other water shares are generally tied to use at specific locations which preclude trading to upstream of the choke from elsewhere.

Table 18: Environmental water currently held by other agencies in River Murray upstream of Barmah Choke

Water holding	Volume	Comments
Water Sharing Plan for the NSW Murray and Lower Darling Regulated Rivers Water Sources – **Adaptive Environmental Water**	30,000 unit shares conveyance (broadly equivalent to ~15,000 ML high security and ~15,000 ML low security). 2,027 unit shares high security (~2,000 ML).	This plan is currently suspended but will recommence from July 1 2011.
Water Sharing Plan for the NSW Murray and Lower Darling Regulated Rivers Water Sources – **Murray Additional Environmental Allowance**	0.03 ML per unit share of high security (~6,000 ML).	This plan is currently suspended but will recommence from 1 July 2011.
Water Sharing Plan for the NSW Murray and Lower Darling Regulated Rivers Water Sources – **Barmah-Millewa Allowance Environmental Water Allocation (NSW)**	50,000 ML when NSW high security allocation is >=97% plus 25,000 ML when Victorian low reliability water share allocation is >30%.	This plan is currently suspended but will recommence from 1 July 2011. Account can be accrued over several years. The maximum credit that can be held against the allowance is 350 GL.
Victorian Minister for Environment (in Trust for Snowy Recovery) – **Barmah-Millewa Forest Environmental Water Allocation (Vic)**	50,000 ML allocated based on Victorian high reliability water share allocations plus 25,000 ML when Victorian low reliability water share allocation is >30%.	Account can be accrued over several years.
Victorian Minister for Environment (in Trust for Snowy Recovery) – **Snowy Environmental Reserve**	29,794 ML high reliability water share.	Total available upstream and downstream of the Choke.
River Murray – Flora and Fauna Conversion Further Amending Order (2009) – **The Living Murray**	40,298 ML low reliability water share. 3,630 ML high reliability water share.	
The Living Murray – **NSW Murray system**	1,887 ML high security. 134,387 general security. 350,000 ML supplementary. 12,965 ML unregulated.	Total available upstream and downstream of the Choke.

8.2 Seasonal allocations

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

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

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

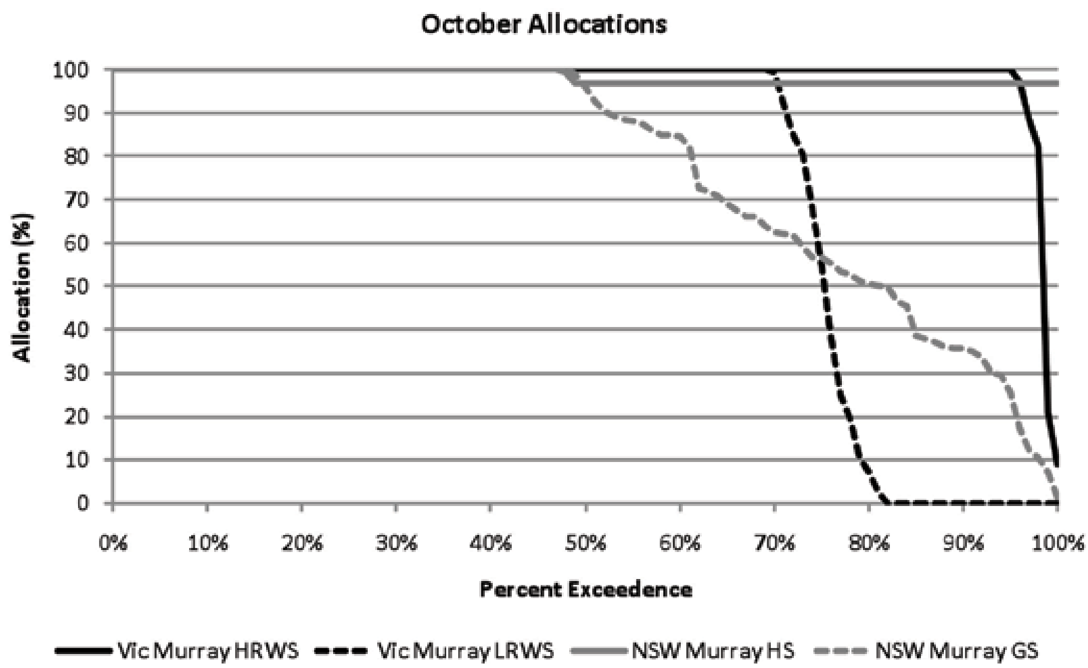

Figure 10: October seasonal allocations for the Murray system

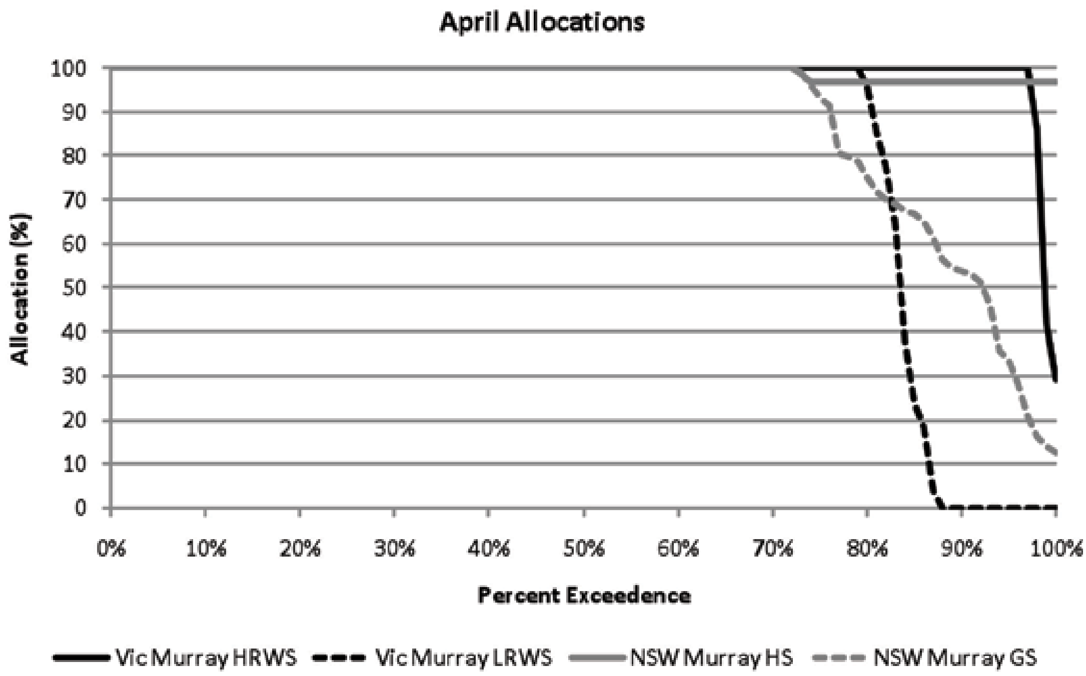

Figure 11: April seasonal allocations for the Murray system

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

This table shows, for example, that allocations could result in approximately 5,000 ML of water being available for use above the choke in spring in a very dry year and 193,000 ML of water available above the choke in a wet year (based on October 2010 water holdings). If water is traded from other locations within the connected southern Murray-Darling Basin, then up to 44,000 ML could be available in spring in a very dry year and up to 502,000 ML could be available in spring in a wet year (based on October 2010 water holdings), subject to any trading constraints outlined in Section 6.3.1.

Table 19: Likely announced allocation

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

Table 20: Likely volume available to the environment (as at October 2010)

River System	Security	Registered Entitlements (ML) (Oct 2010)	Water Availability							
			October Allocation (GL)				April Allocation (GL)			
			Very Dry	Dry	Median	Wet	Very Dry	Dry	Median	Wet
NSW Murray above Barmah Choke	General Security	155,752.0	2.2	97.2	149.1	155.8	19.3	155.8	155.8	155.8
Victorian Murray above Barmah Choke	High reliability water share	32,361.3	2.9	32.4	32.4	32.4	9.4	32.4	32.4	32.4
	Low reliability water share	5,674.1	0.0	5.6	5.7	5.7	0.0	5.7	5.7	5.7
Ovens*	High reliability water share	70.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total above Barmah Choke			**5.1**	**135.2**	**187.2**	**193.8**	**28.7**	**193.8**	**193.8**	**193.8**
NSW Murray below Barmah Choke	High security	386.0	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4
	General Security	32,558.0	0.5	20.3	31.2	32.6	4.0	32.6	32.6	32.6
Victorian Murray below Barmah Choke	High reliability water share	78,721.9	7.1	78.7	78.7	78.7	22.8	78.7	78.7	78.7
	Low reliability water share	5,451.3	0.0	5.4	5.5	5.5	0.0	5.5	5.5	5.5
Murrumbidgee*	General Security	64,959.0	6.5	27.3	35.7	41.6	6.5	44.2	65.0	65.0
	Supplementary	20,820.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Goulburn	High reliability water share	64,919.6	13.0	64.9	64.9	64.9	18.2	64.9	64.9	64.9
	Low reliability water share	10,480.0	0.0	0.4	5.7	10.0	0.0	1.8	8.2	10.5
Broken*	High reliability water share	20.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Low reliability water share	4.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

River System	Security	Registered Entitlements (ML) (Oct 2010)	Water Availability							
			October Allocation (GL)				April Allocation (GL)			
			Very Dry	Dry	Median	Wet	Very Dry	Dry	Median	Wet
Campaspe	High reliability water share	5,124.1	1.7	5.1	5.1	5.1	2.2	5.1	5.1	5.1
	Low reliability water share	395.4	0.0	0.4	0.4	0.4	0.0	0.4	0.4	0.4
Loddon	High reliability water share	1,179.0	0.0	1.2	1.2	1.2	0.0	1.2	1.2	1.2
	Low reliability water share	527.3	0.0	0.0	0.3	0.5	0.0	0.1	0.4	0.5
South Australia	High reliability	43,297.4	19.0	43.3	43.3	66.9	26.6	43.3	43.3	44.3
Total below Barmah Choke			**48.1**	**247.4**	**272.3**	**307.7**	**80.8**	**278.1**	**305.6**	**309.0**
Total			**53.2**	**382.6**	**459.5**	**501.5**	**109.5**	**471.8**	**499.4**	**502.8**

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

8.3 Water availability forecasts

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

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

A description of likely water availability for the Victorian Murray System is provided by Goulburn-Murray Water when allocation announcements are made (on the 1st and 15th of each month or the next business day). The current allocation announcement and a description of likely future water availability for the remainder of the season can be sourced from: http://g-mwater.com.au/news/allocation-announcements/current.asp. Historical announcements and forecasts can be sourced from: http://g-mwater.com.au/news/allocation-announcements/archive.asp. Additionally, Goulburn-Murray Water publishes a seasonal allocation outlook prior to the start of each irrigation season to give a forecast for October and February allocations for the following season. The seasonal allocation outlooks are published on Goulburn-Murray Water's website (see Media Releases). Note that in years with high water availability, only the seasonal allocation outlook may be prepared (i.e. water availability forecasts may not be provided with allocation announcements).

PART 3:
Monitoring and future options

9. Monitoring evaluation and improvement

9.1 Existing monitoring programs and frameworks

There is limited routine monitoring undertaken in the Edward-Wakool system. There are various measuring points for environmental water. Key points are the regulators into Werai Forest, which are measured by field staff as required, and continuous flow monitoring points throughout the system. Instantaneous level, discharge, salinity (electrical conductivity) and temperature are recorded at a number of locations. A list of key sites is provided in Table 21. For a full list of sites and the parameters monitored at each site, refer to the NSW Water Information website http://waterinfo.nsw.gov.au/ and MDBA real-time data website at http://www.mdba.gov.au/water/live-river-data/yarrawonga-to-euston).

Table 21: Selected flow and water quality monitoring in the Edward-Wakool

Site number	Site name	Relevance to this plan
409003	Edward R at Deniliquin	Only gauged intermittently
409008	Edward R at offtake	Regulated inflows to Edward R
409013	Wakool R at Stoney Crossing	Outflows from Wakool R to River Murray
409014	Edward R at Moulamein	Outflows from Edward R to River Murray
407017	River Murray at Doctors Point	Indicates flooding of land on River Murray
409019	Wakool R offtake regulator	Wakool R offtake from Edward R
409020	Yallakool Ck at offtake	Yallakool Ck offtake from Edward R
409021	Wakool Main Canal	Offtake from Colligen Ck
409023	Edward R d/s of Stevens Weir	Indicator for Werai Forest inflows
409024	Colligen Ck below regulator	Colligen Ck d/s Wakool Canal
409025	River Murray d/s of Yarrawonga Weir	Triggers delivery of environmental water
409026	Mulwala Canal	Offtake from Yarrawonga Weir
409029	Mulwala Canal Escape	Outfalls to Edward R
409030	Gulpa Ck	Regulated inflows to Gulpa Ck
409036	Merran Ck u/s Wakool Junction	Outflows from Merran Ck to Wakool R
409044	Little Merran Ck at Franklings Bridge	Flow through Merran Cutting
409047	Edward R at Toonalook	Flow site u/s of Deniliquin
409056	Tuppal Ck at Aratula Rd	Flow site u/s of Deniliquin
409075	Bullatale Ck at u/s Edward R	Flow site u/s of Deniliquin
409086	Niemur R at Mallans School	Outflow from Niemur R to Wakool R
409098	Waddy Ck at d/s of regulator	Flow into Waddy Ck from River Murray

The Murray Region Algal Monitoring Program covers a small number of locations within the Edward-Wakool System, and monthly blue-green algal counts are conducted on the Edward River. Included in this program is less regular monitoring of dissolved oxygen, turbidity and pH (NSW Water Information).

In addition there are a number of one-off investigations and specific research activities. Recent investigations include:

- Industry and Investment NSW (I&I NSW) and Murray Catchment Management Authority joint project monitoring native fish response to flows.
- Assessment of acid sulphate soils in wetlands (Ward et al. 2010);
- Assessment of the causes and management of blackwater events in the system (Watkins et al. 2010; Baldwin 2009);
- Assessment of fish and drought refuges in the Wakool system (Gilligan et al. 2009);
- Assessment of fish populations and movements (Murray CMA);
- Environmental monitoring (water quality, waterbirds and other fauna) associated with environmental water allocations to Werai forests (e.g. Webster 2010); and
- Blackwater monitoring of 2010 flood events (TLM).

9.2 Operational water delivery monitoring

State Water and OEH provide a log of actions in any watering event to provide environmental flows. Environmental water managers should request that State Water and OEH commence documentation of watering events as they occur and finalise documentation as soon as the watering event has been completed. The Department of Sustainability, Environment, Water, Populations and Communities' pro-forma for an operational monitoring report is contained in Appendix C. This information can provide input into future environmental water delivery, as well as any applications for return flow credits to the NSW State Government.

9.3 Key parameters for monitoring and evaluating ecosystem response

Recommended monitoring to inform management of environmental water in the Edward-Wakool system and inform on the success of the program is summarised in Table 22.

Table 22: Monitoring plan for environmental water use

Ecological target	Hypotheses	Flow component	Indicator(s)	Monitoring sites	Frequency	Linkages and responsibility
Maintain water quality within channels and pools. Reduce the frequency and magnitude of blackwater events.	Baseflows during late winter / early spring; through to summer will prevent accumulation of litter in channel and reduce blackwater events.	Base flow	Litterfall Dissolved oxygen (DO)	Waterholes and streams: Colligen Creek, Niemur and Wakool Rivers.	Litterfall prior to flooding dry channels, DO monthly during inundation.	Recommended by Watkins et al. (2010). Litter not currently included in any monitoring programs. DO measured by NSW Office of Water algal monitoring program.
Promote productivity to maintain food webs and ecosystem function for in-channel flora and fauna.	Baseflows during late winter / early spring, when weather is cooler, followed by spring pulses will promote productivity.	Baseflow, spring pulses	Phytoplankton, macroinvertebrates, fish abundance.	Wakool, Niemur and Edwards Rivers, Colligen Creek.	To coincide with spring pulses.	Not currently monitored. NSW Office of Water also manages the algal monitoring program that provides counts of blue-green algae. Would need to be established with relevant agencies (Murray CMA, NSW Office of Water, Environmental Water Manager).
Maintain connectivity between main channel and lower commence to fill billabongs and backwaters.	Baseflows provided between July and December will connect pools and wetlands.	Baseflow	Stream flow and height.	Wakool, Niemur and Edwards Rivers, Colligen Creek.	Continuous	NSW Office of Water manages current instantaneous level and discharge at a number of gauging stations in the system. This may not provide sufficient information on connectivity with billabongs and backwaters.
Provide fish passage, successful fish recruitment. Maintain connectivity through the forest (Tumudgery Creek and Reed Beds Creek from Edward River to Colligen-Neimur) between river channel and low lying wetlands for fish and other aquatic fauna.	Instigation of spring pulses will promote successful fish recruitment. Environmental water allocations will improve fish passage through the system.	Baseflow, spring pulses.	Radio-tracking of native fish, fish community composition and abundance,	Yallakool / Wakool River	To coincide with spring pulses.	DPI NSW and Murray CMA joint program is providing comprehensive monitoring and investigation of native fish spawning over the next three years.
Maintain inundation of low lying wetlands associated with the river channels to prevent exposure of acid sulphate soils.	Baseflows between July and December will maintain inundation of low lying wetlands and prevent formation of sulphuric acid.	Baseflow	pH, salinity	Boiling Downs Creek, Glen Esk-Rusty Waterhole and Wakool River Billabong, other potential sites in the Wakool, Colligen and Niemur systems.	Monthly	NSW Office of Water also manages the algal monitoring program that includes pH. NSW Office of Water manages current instantaneous salinity and temperature monitoring at a number of gauging stations in the system.

Ecological target	Hypotheses	Flow component	Indicator(s)	Monitoring sites	Frequency	Linkages and responsibility
Prevent low dissolved oxygen events in channel systems by instigating diluting flows prior to and during water entering channels from floodplain environments.	Presence of water in streams will dilute low dissolved oxygen / high organic carbon coming of the floodplains.	Baseflow, spring pulses.	Dissolved oxygen, dissolved organic carbon.	Wakool River, Colligen Creek, Edwards River.	To coincide with floodplain inundation.	Not specifically monitored. DO measured by NSW Office of Water algal monitoring program. Would need to be established with relevant agencies (Murray CMA, NSW Office of Water, Forests NSW, Envitonmental Water Manager).
Maintain extent and health of reed bed vegetation.	Regular (1 to 3 year frequency) inundation of Reed Bed Creek Wetlands will maintain extent and composition of aquatic macrophytes.	Spring pulses, Werai watering.	Extent and composition of aquatic vegetation.	Reed Bed Creek Wetlands.	To coincide with Werai inundation.	Not currently monitored, but identified as a requirement under the ECD for Central Murray Forests Ramsar site. May be included by NPWS monitoring.
Maintain health of river red gum forests and woodlands.	Regular (2 to 5 year frequency) inundation of river red gum forests will maintain extent and maintain / improve condition.	Spring pulses, floodplain watering.	Extent and canopy condition of floodplain forests.	Werai, Niemur Forests.	3–6 months post floodplain inundation.	TLM measures for icon sites, but not in Werai. May be included by NPWS monitoring.
Maintain the health of Black Box woodlands.	Regular (5 to 8 year frequency) inundation of river black box woodlands will maintain extent and maintain / improve condition.	Spring pulses, floodplain watering.	Extent and canopy condition of floodplain forests.	Werai, Lake Agnes.	3–6 months post floodplain inundation.	TLM measures for icon sites, but not in Werai. May be included by NPWS monitoring.
Promote successful breeding of waterbirds.	Inundation of wetlands for 3 to 4 months will instigate successful waterbird breeding.	Spring pulses, Floodplain watering.	Nest counts, recruitment.	Werai, Niemur Forests.	To coincide with wetland / floodplain inundation.	Not currently monitored, but identified as a requirement under the ECD for Central Murray Forests Ramsar site. May be included by NPWS monitoring.
Maintain health of ephemeral wetlands and watercourses.	Periodic inundation of ephemeral wetlands and watercourses will maintain / improve biodiversity.	Moderate to large watering events.	Community composition and abundance: macroinvertebrates, fish, aquatic vegetation.	Cockran Creek, Yarrien Creek; and Poon Boon Lakes.	To coincide with watering events.	Not currently monitored. Would need to be established with relevant agencies (Murray CMA, NSW Office of Water, Environmental Water Manager).

10. Opportunities

Some effluent creeks have been disconnected from the River Murray to protect Tocumwal and surrounding agricultural land from flooding. Better connectivity between the Edward River and the River Murray could be required to more efficiently deliver environmental flows; however this would require significant investigation and on-ground works. Options to improve connectivity between the River Murray and Tuppal Creek are being investigated by Murray CMA (2010) and include constructing a flow regulator through the levee bank and purchasing downstream flood easements.

The use of Millewa Forest regulators to deliver water to the Edward-Wakool system is considered feasible when undertaken in conjunction with a Millewa Forest watering. The ability to use these regulators for the primary purpose of delivering water through to the Edward River is not well known and may provide opportunities to reduce the River Murray volumes needed to increase flows in the Edward River.

Werai Forest is a throughflow wetland on a broad floodplain. There are currently no feasible opportunities to introduce structures to the forest to reduce watering requirements.

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

The accounting rules for the Edward-Wakool system attribute forfeited water to NSW rather than being shared between States, as they are in the River Murray. Alternative methods of accounting for system forfeit in the Edward-Wakool could allow for more flexibility in the delivery of baseflows throughout the system, and requires further investigation.

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Appendix A: Significant flora and fauna

Significant species in the Edward-Wakool system (Herring et al. 2006; MDBA 2010a).

Common Name	Scientific Name	EPBC Status	TSA Status	Presence
Eastern great egret	*Ardea modesta*	Marine, Migratory		Known
Cattle egret	*Ardea ibis*	Marine, Migratory		Known
White-bellied sea eagle	*Haliaeetus leucogaster*	Marine, Migratory		Known
Forked-tailed swift	*Apus pacificus*	Migratory	Endangered	May
Latham's snipe	*Gallinago hardwickii*	Migratory	Vulnerable	May
White-throated needletail	*Hirundapus caudacutus*	Migratory	Vulnerable	Known
Australian painted snipe	*Rostralula australis*	Endangered	Vulnerable	May
Australasian bittern	*Botaurus poiciloptilus*	(Endangered IUCN Red List)	Endangered	Known
Regent Honeyeater	*Xanthomyza phrygia*	Endangered	Endangered	May
Swift Parrot	*Lathamus discolor*	Endangered	Vulnerable	Likely
Malleefowl	*Leipoa occelata*	Endangered	Vulnerable	Likely
Bush Stone-curlew	*Burhinus grallarius*		Endangered	Known
Superb Parrot	*Polytelis swainsonii*	Vulnerable	Endangered	Known
Magpie goose	*Anseranas semipalmata*		Vulnerable	Known
Freckled duck	*Stictonetta naevosa*		Vulnerable	Known
Blue-billed duck	*Oxyura australis*		Vulnerable	Known
Brolga	*Grus rubicunda*		Vulnerable	Known
Black-tailed godwit	*Limosa limosa*		Vulnerable	Known
Painted honeyeater	*Grantiella picta*		Vulnerable	Known
Black-chinned honeyeater	*Melithreptus gularis*		Vulnerable	Known
Hooded robin	*Melanodryas cucullata*		Vulnerable	Known
Grey-crowned babbler	*Pomatostomus temporalis temporalis*		Vulnerable	Known
Gilbert's whistler	*Pachycephala inornata*		Vulnerable	Known
Diamond firetail	*Stagonopleura guttata*		Vulnerable	Known
Murray cod	*Maccullochella peelii peelii*	Vulnerable	Vulnerable	Known

Common Name	Scientific Name	EPBC Status	TSA Status	Presence
Eel tailed catfish	*Tandanus tandanus*		Endangered population (MDB)	Likely
Murray hardyhead	*Craterocephalus fluviatilis*	Vulnerable	Vulnerable	May
Silver perch	*Bidyanus bidyanus*		Vulnerable	Known
Trout cod	*Maccullochella macquariensis*	Endangered		Known
Southern bell frog	*Litoria raniformis*	Vulnerable		Known
Spotted-tailed quoll	*Dasyurus maculatus*	Endangered	Vulnerable	Likely
Large-footed myotis	*Myotis adversus*		Vulnerable	Likely
Eastern long-eared bat	*Nyctophilus timoriensis*	Vulnerable	Vulnerable	Likely
Squirrel glider	*Petaurus norfolcensis*		Vulnerable	Known
Little pied bat	*Chalinolobus picatus*		Vulnerable	Known

Appendix B: Mulwala Canal airspace

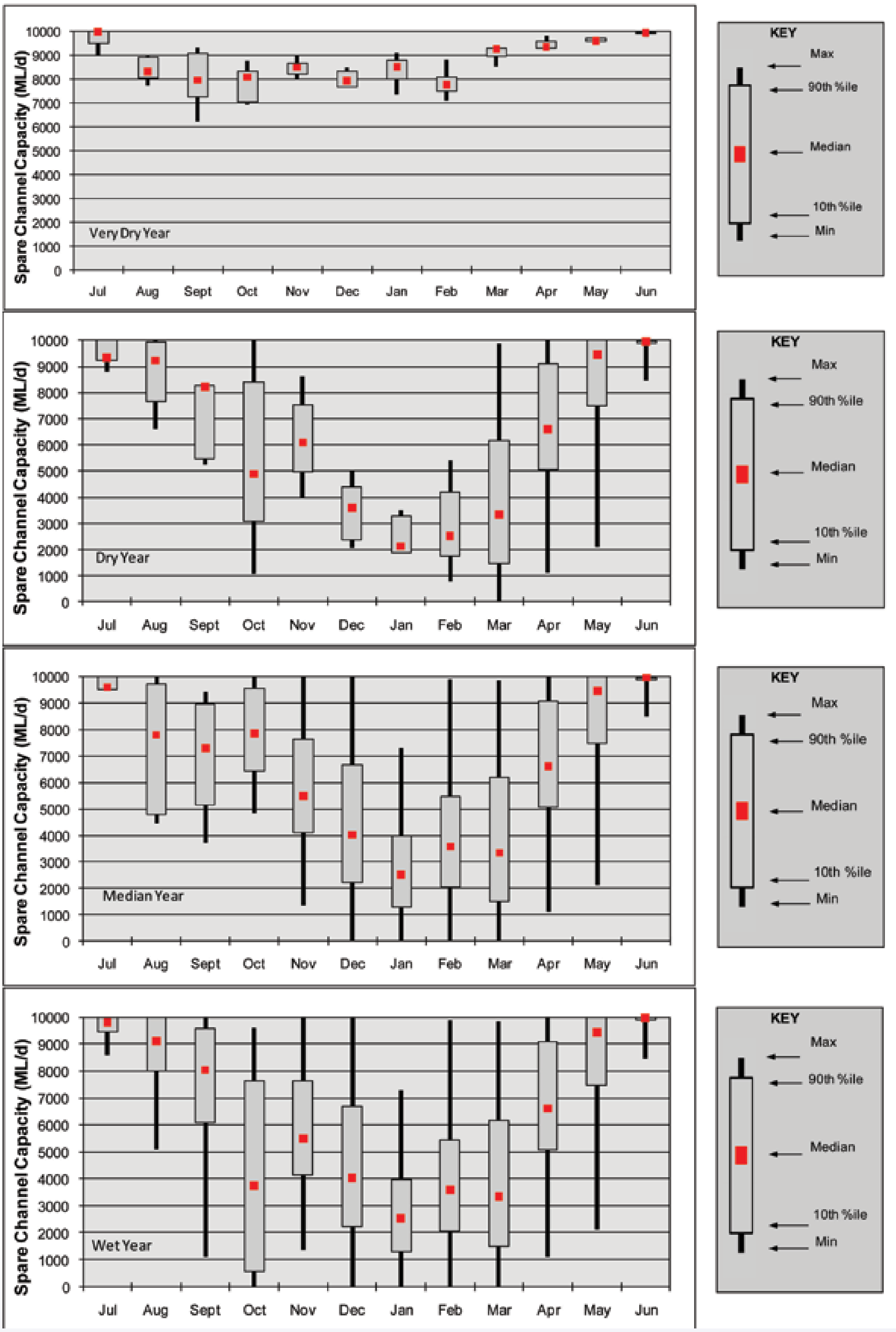

Figure 12: Spare channel capacity in Mulwala Canal, 1895–2009 (min, 10th percentile, median, 90th percentile and maximum daily values)

Appendix C: Operational Monitoring Report Template

Commonwealth Environmental Watering Program

Operational Monitoring Report

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

Final Operational Report | Intermediate Operational Report | Reporting Period: From | To

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

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

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

Appendix D: Risk Assessment Framework

Table 23: Risk likelihood rating

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

Table 24: Risk consequence rating

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

Table 25: Risk analysis matrix

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

WAT088.0211