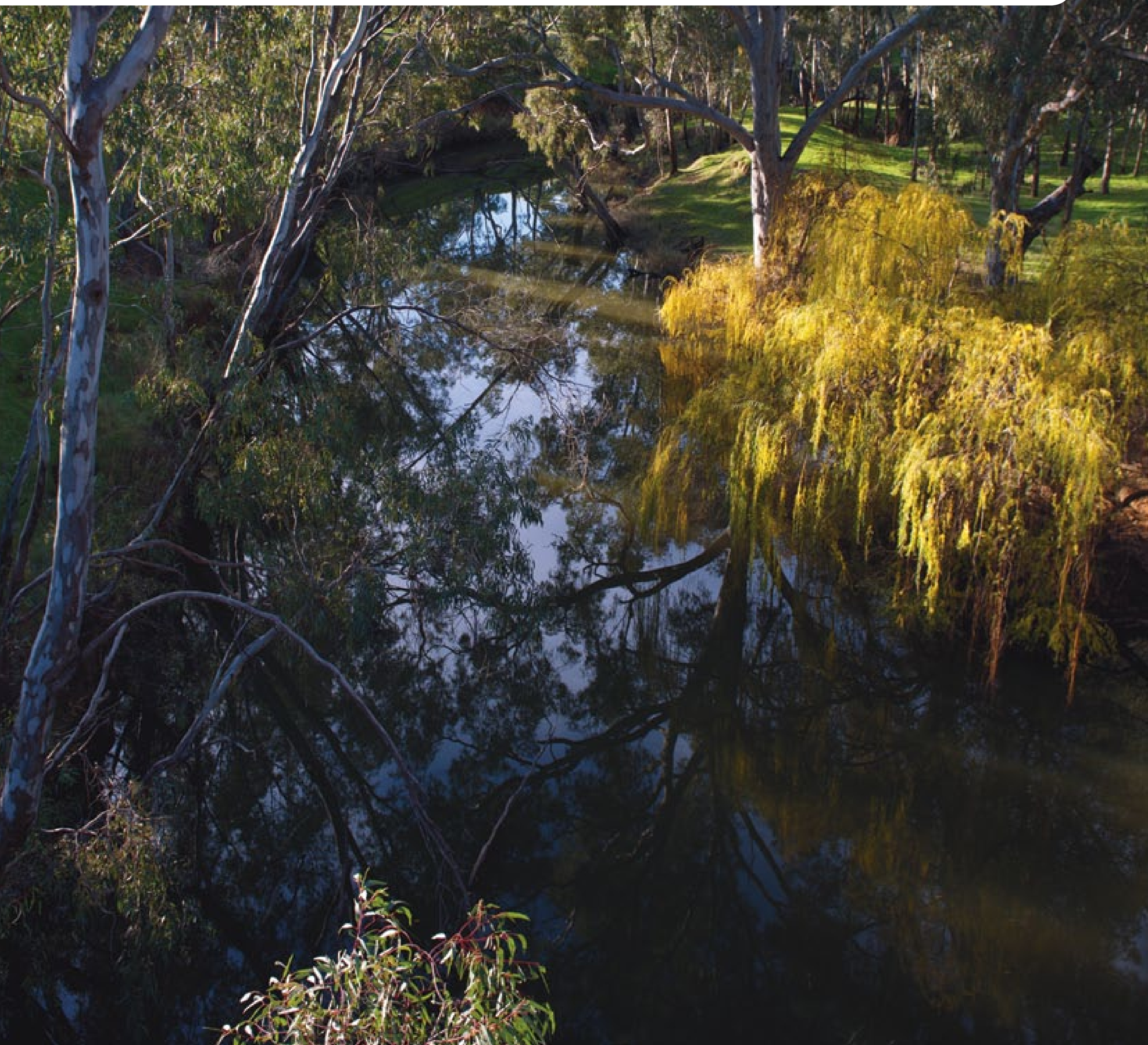
Australian Government

Commonwealth Environmental Water

ENVIRONMENTAL WATER DELIVERY

CAMPASPE RIVER

AUGUST 2011 V1.0



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CAMPASPE RIVER

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Environmental Water Delivery: Campaspe River

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

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

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

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

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

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

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

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Contents

Figures

Tables

Acronyms

ACRONYM	MEANING
BE	Bulk entitlement
CEWH	Commonwealth Environmental Water Holder
COAG	Council of Australian Governments
DO	Dissolved oxygen
DPI	Victorian Department of Primary Industries
DSE	Victorian Department of Sustainability and Environment
EPBC Act	*Environment Protection and Biodiversity Conservation Act 1999* (Commonwealth)
EVC	Ecological vegetation classes
eWater CRC	Environmental Water Co-operative Research Centre
EWRs	Environmental Water Holders
GBCL	Goulburn-Broken-Campaspe-Loddon
GB CMA	Goulburn Broken Catchment Management Authority
G-MW	Goulburn-Murray Water
IVTs	Inter-valley transfers
MDBA	Murray-Darling Basin Authority
NC CMA	North Central Catchment Management Authority
NERWMP	North East Regional Water Monitoring Partnership
RHS	North Central River Health Strategy
NRSWS	The Northern Region Sustainable Water Strategy
NVIRP	Northern Victoria Irrigation Renewal Project
SEWPaC	Australian Government Department of Sustainability, Environment, Water, Population and Communities
VEFMAP	The Victorian Environmental Flows Monitoring and Assessment Program
VEWH	Victorian Environmental Water Holder
VWQMN	Victorian Water Quality Monitoring Network

PART 1:
Management Aims

1. Overview

1.1 Scope and purpose of this document

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

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

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

This work has been undertaken in three steps:

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

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

1.2 Catchment and river system overview

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

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

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

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

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

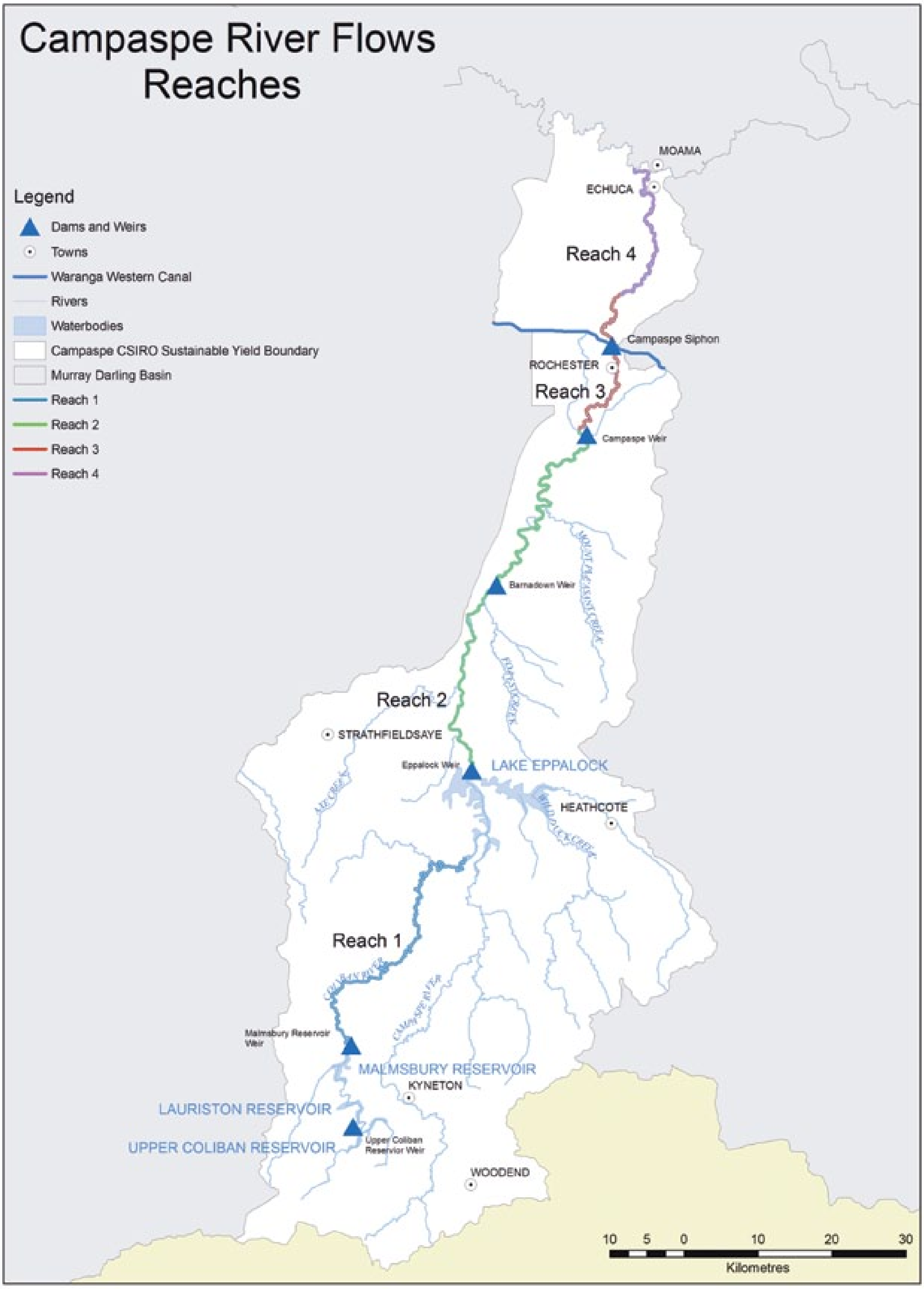


Figure 1: Regulated reaches of the Campaspe River (SEWPaC 2011).

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

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

1.3 Overview of river operating environment

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

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

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

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

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

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

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

2. Ecological values, processes and objectives

2.1 Summary of ecosystem values

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

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

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

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

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

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

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

More detailed objectives are presented in Section 3.1.

3. Watering objectives

3.1 Broad-scale ecosystem objectives

3.1.1 Murray-Darling Basin

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

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

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

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

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

3.2 Proposed asset watering objectives

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

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

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

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

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

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

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

3.3 Summary of watering objectives

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

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

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

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

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

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

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

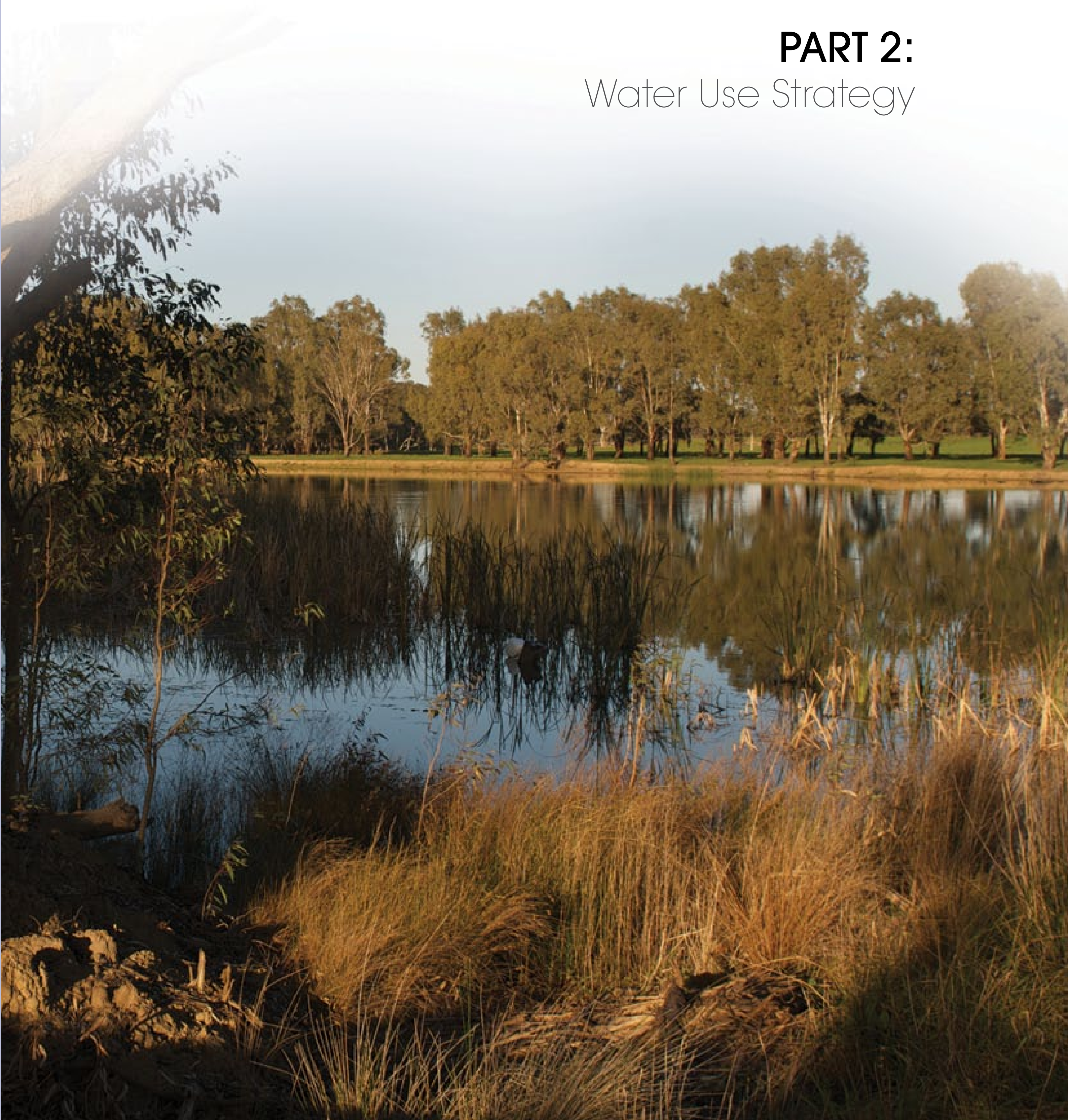
Objectives and potential watering options for Reaches 2 and 4 using environmental water are presented in Table 6. Preference is given by the North Central CMA and VEWH to delivering all the proposed flow components to Reach 4 from Lake Eppalock, as this would result in a connected river and multi-use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

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

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

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

PART 2:
Water Use Strategy



4. Environmental water requirements

4.1 Baseline flow characteristics

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

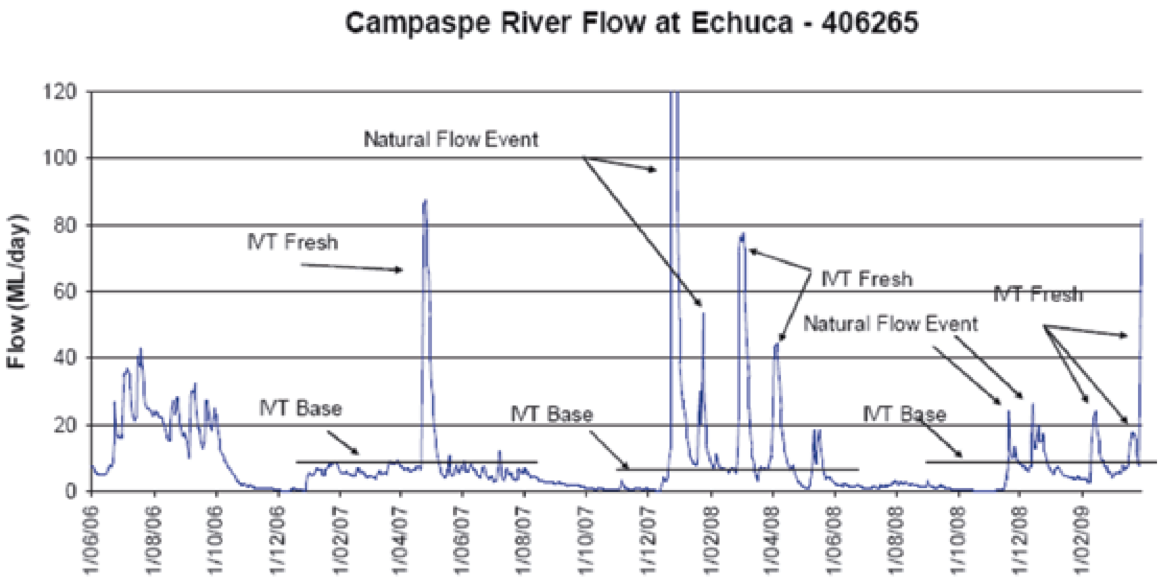


Figure 2: Flow in the Campaspe River at Echuca, and the contribution from inter valley trade (North Central CMA 2010).

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

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

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

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

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

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

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

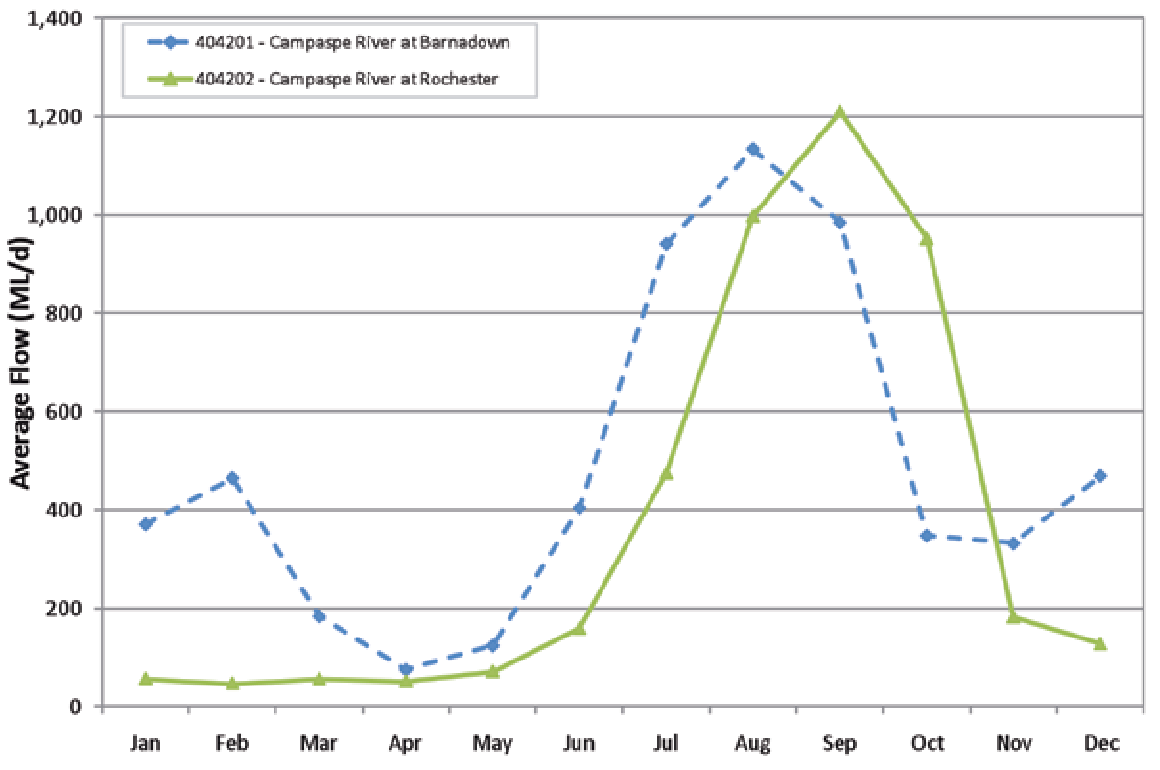


Figure 3: Average daily flow recorded at streamflow gauges at Barnadown (404201) and Rochester (404202) between 1977 and 2009.

4.2 Environmental water demands

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

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

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

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

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

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

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

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

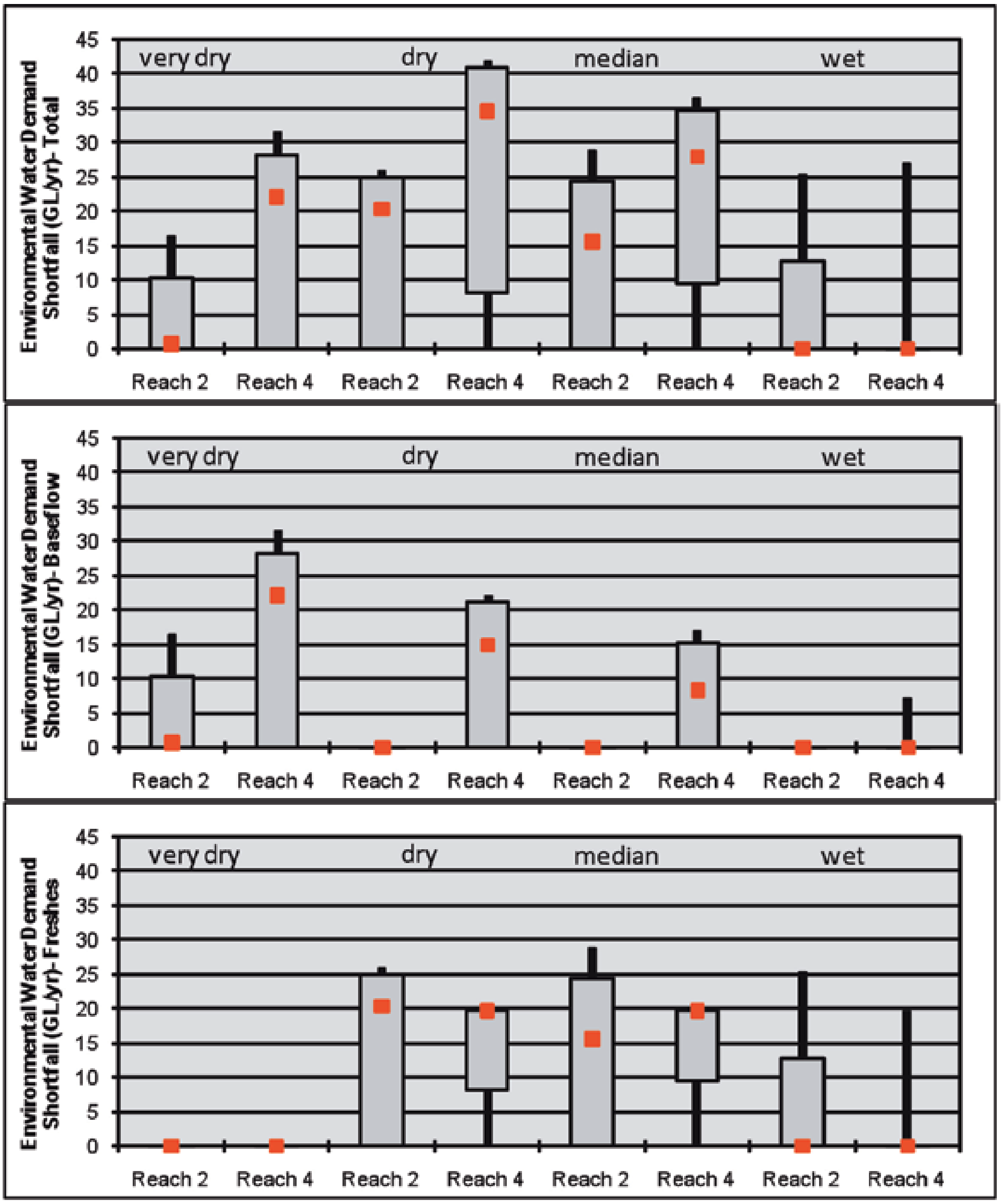


Figure 4: Shortfalls at the delivery site in meeting the winter environmental water demand in Reach 2 and Reach 4 of the Campaspe River (1895–2009). Median values are indicated by red boxes.

5. Operating regimes

5.1 Introduction

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

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

5.2 Identifying target environmental flow proposals

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

Table 9: Identifying seasonal target environmental flow proposals.

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

5.3 Delivery triggers

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

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

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

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

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

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

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

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

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

5.4 Storage releases

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

5.5 Channel capacity

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

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

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

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

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

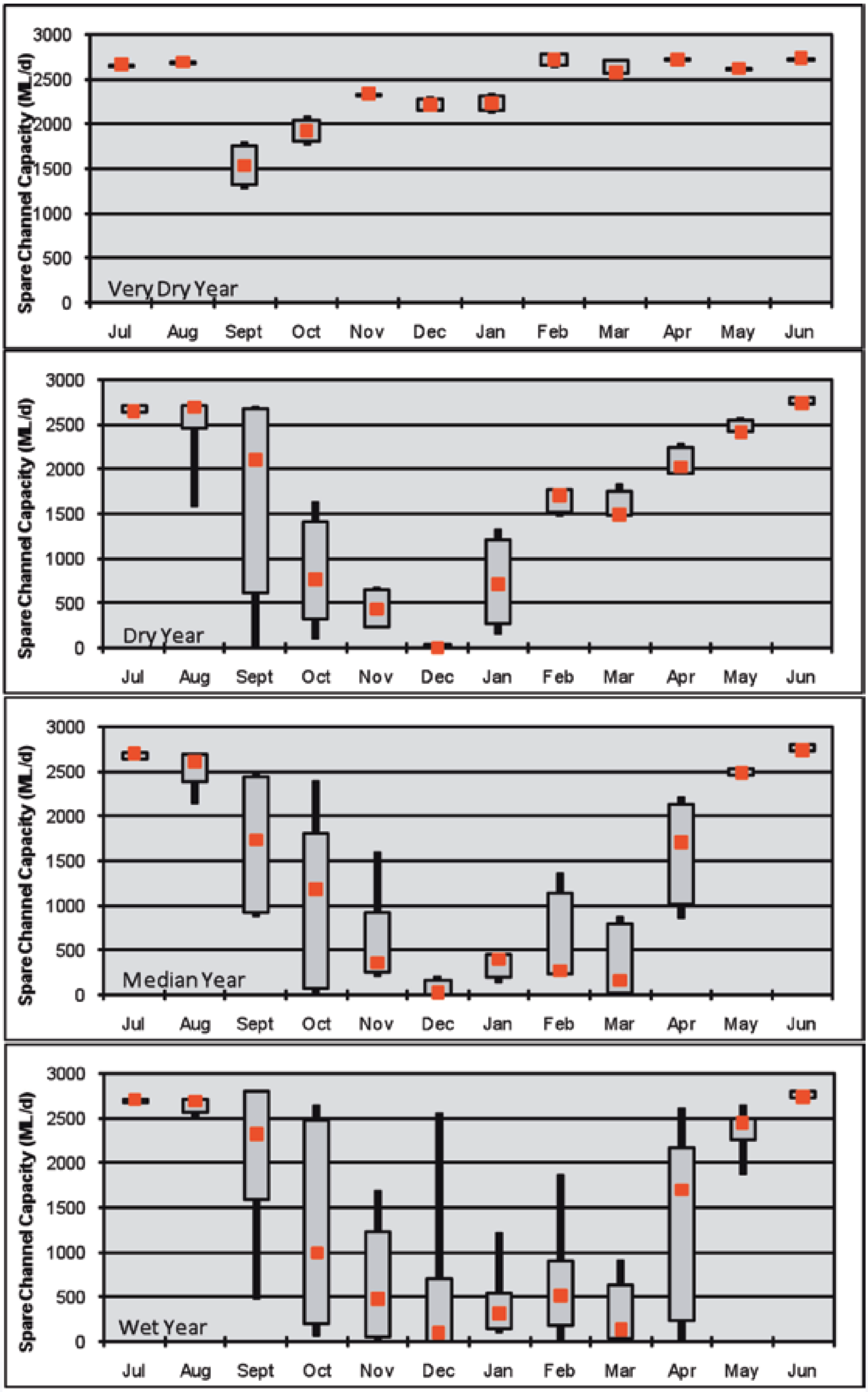


Figure 5: Spare channel capacity in the Waranga Western Main Channel upstream of the Campaspe Siphon, 1895–2009. Median values are indicated by red boxes.

5.6 Travel time

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

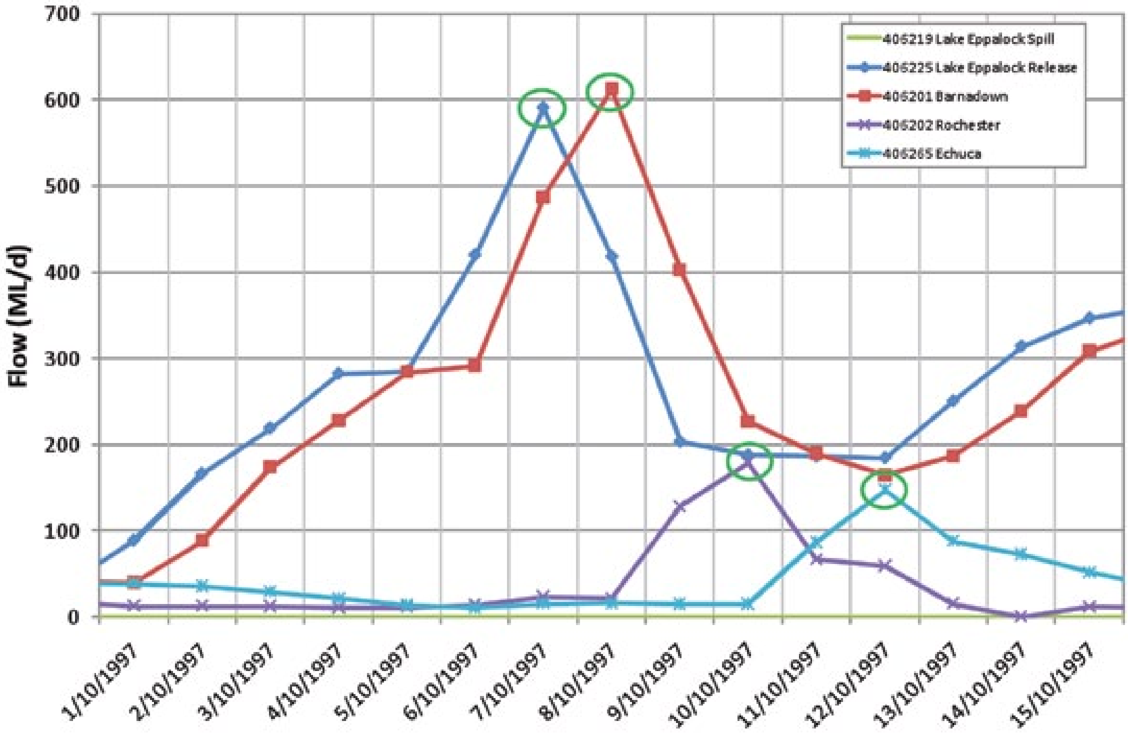


Figure 6: Travel time for a release from Lake Eppalock to reach the confluence of the Campaspe and Murray Rivers, October 1997.

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

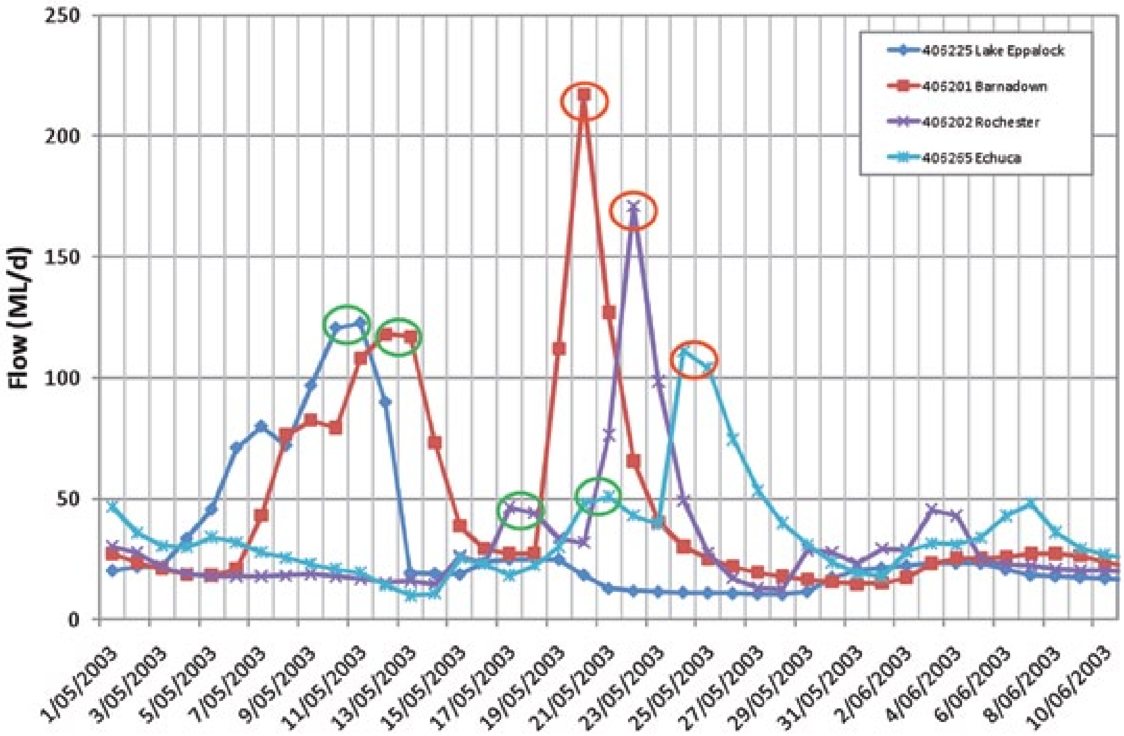


Figure 7: Travel time for a release from Lake Eppalock to reach the Murray River, May 2003.

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

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

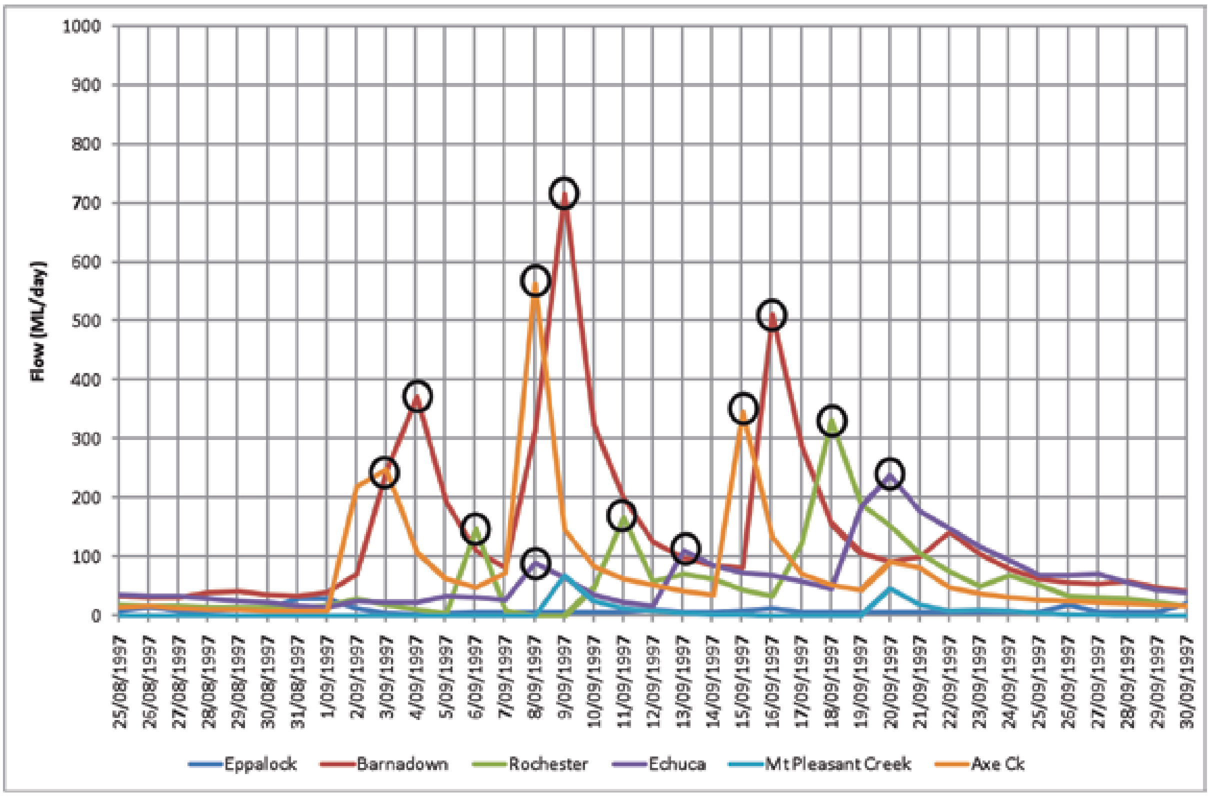


Figure 8: Travel time for a peak in Axe Creek to reach Barnadown and travel downstream.

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

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

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

5.7 Flooding

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

5.8 Water Delivery Costs

5.8.1 Delivery costs

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

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

5.8.2 Carryover costs

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

5.9 Interactions with other assets

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

6. Governance and planning arrangements

6.1 Delivery partners, roles and responsibilities

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

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

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

6.2 Approvals, licenses, legal and administrative issues

6.2.1 Water shepherding and return flows

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

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

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

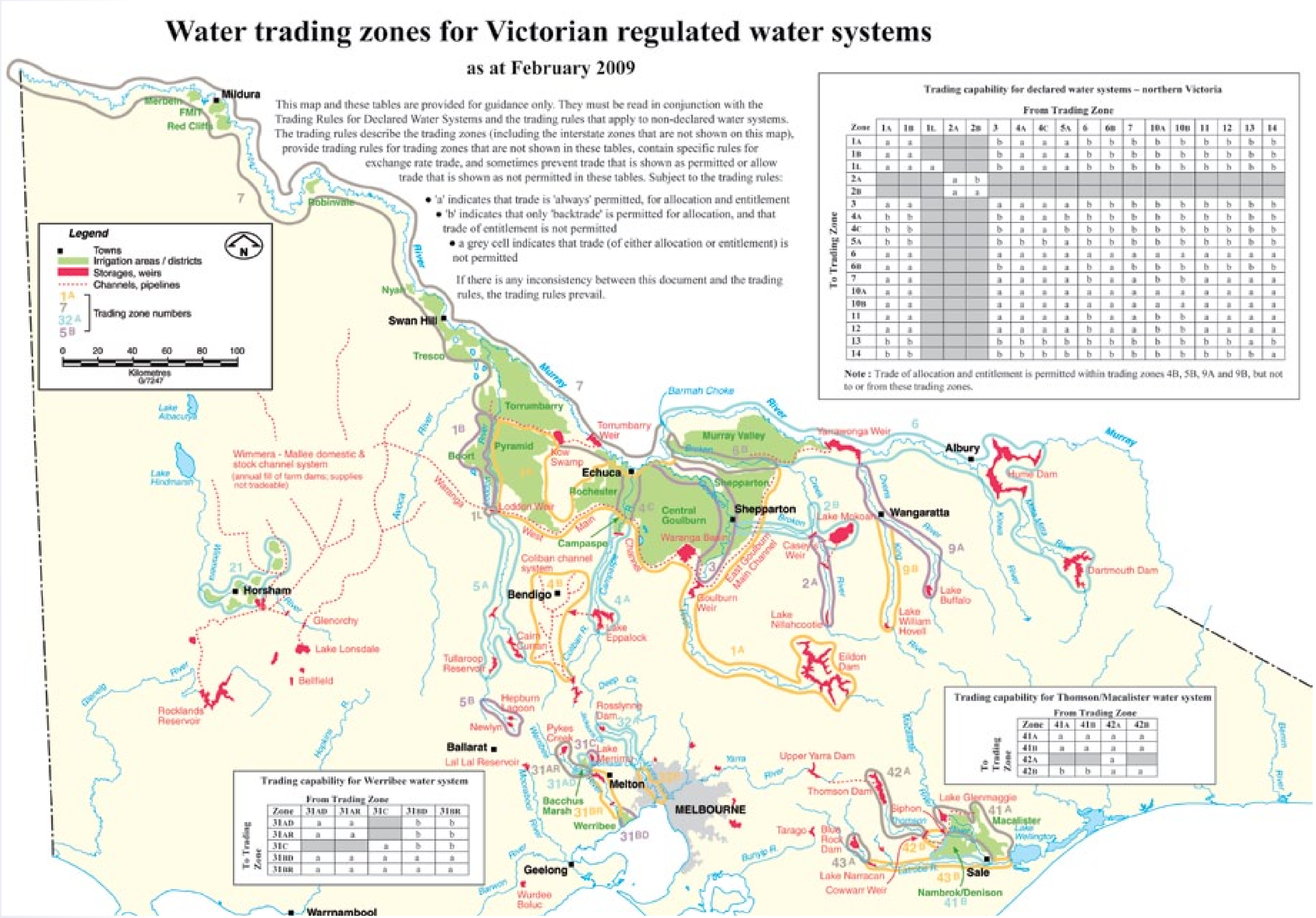
If Commonwealth environmental water allocations are temporarily transferred to the Flora and Fauna entitlement, then return flows to the Murray River can readily be credited under Clause 15 of that entitlement. Specified points for diversion and return flows are listed in Schedule 4 to the entitlement;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

If the point of delivery from the Campaspe system is specified as Echuca (the confluence of the Campaspe River and the Murray River), this will ensure all of the regulated reaches of the Campaspe River will benefit from environmental releases from Lake Eppalock. However, if environmental water is delivered to Echuca from the Goulburn system via the Waranga Western Main Channel, only the Campaspe River downstream of The Siphon will benefit.

6.3 Trading rules and system accounting

6.3.1 Water trading

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



From Trading Zone / To Trading Zone

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

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

Trading capability for Werribee water system

From Trading Zone / To Trading Zone

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

Trading capability for Thomson/Macalister water system

From Trading Zone / To Trading Zone

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

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

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

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

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

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

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

Additional Trading Rules

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

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

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

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

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

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

6.3.2 Water storage accounting

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

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

7. Risk assessment and mitigation

The risk assessment outlined in Table 12 provides an indication of some of the risks associated with the delivery of environmental water in the Campaspe catchment. It should be noted that risks are not static and require continual assessment to be appropriately managed. Changes in conditions will affect the type of risks, the severity of their impacts and the mitigation strategies that are appropriate for use. As such, a full risk assessment must be undertaken prior to the commencement of water delivery. A framework for assessing risks has been developed by SEWPaC and is included at Appendix 4.

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

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

8. Environmental water reserves

8.1 Environmental water holdings and provisions

8.1.1 Water planning responsibilities

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

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

8.1.2 Environmental water provisions

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

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

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

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

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

8.1.3 Current water holdings

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

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

Table 14: Commonwealth environmental water holdings (as at October 2010).

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

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

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

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

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

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

8.2 Seasonal allocations

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

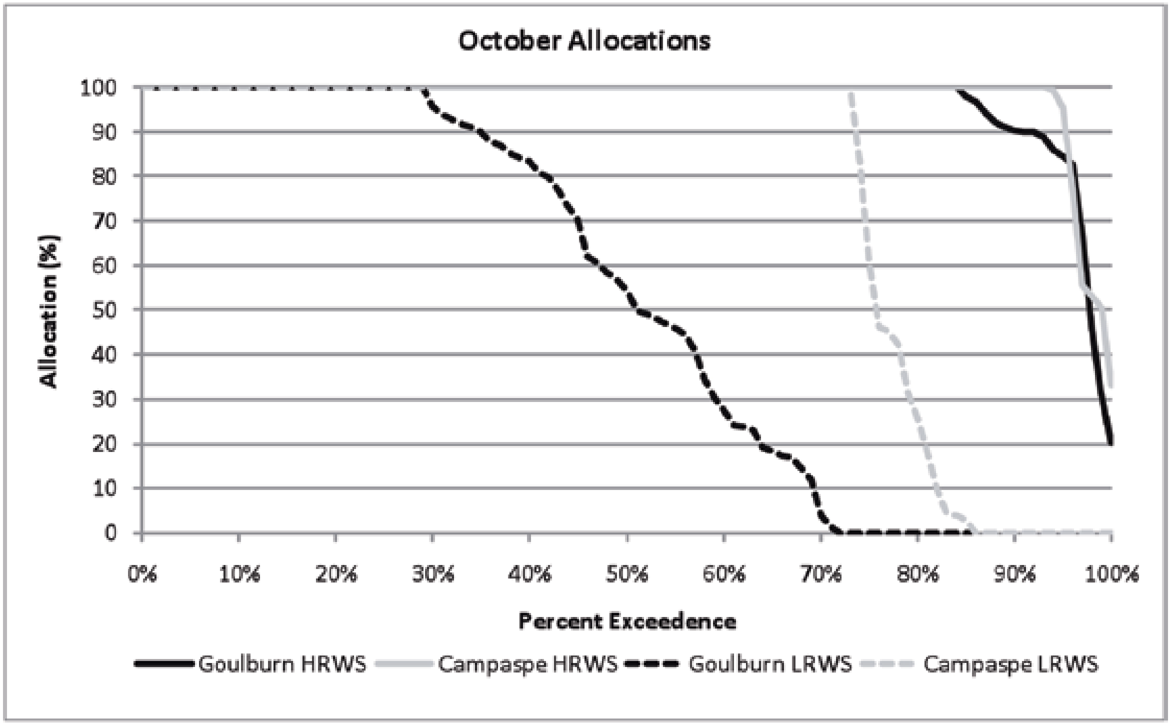


Figure 10: October seasonal allocations for the Campaspe and Goulburn systems.

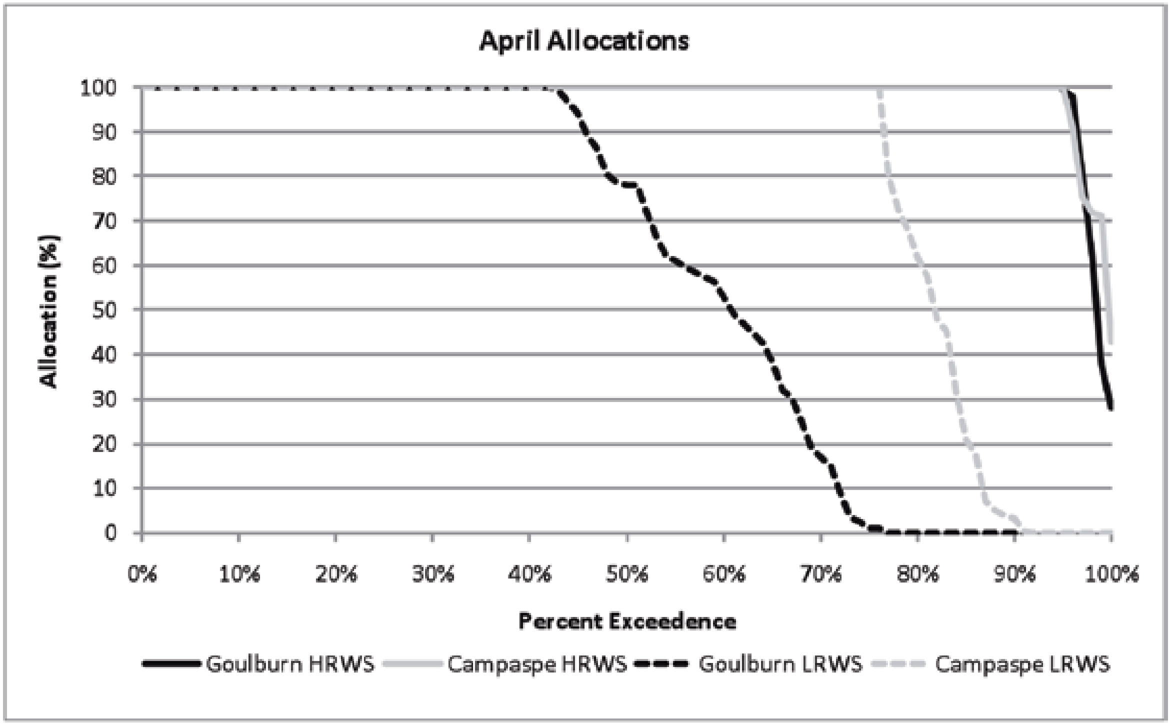


Figure 11: April seasonal allocations for the Campaspe and Goulburn systems.

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

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

The calculation of the volume of water expected to be available to the environment under each climate condition is based on the volume and type of entitlements held and the expected announced allocation for each climate condition (from modelling). As stated previously, the models used to derive these allocations over-estimate allocation in very dry years.

Table 16: Likely allocation under different climate scenarios.

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

Table 17: Likely volume available to the environment from Commonwealth environmental water holdings (as at October 2010).

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

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

8.3 Water availability forecasts

Water availability forecasts for the Campaspe and Goulburn systems are provided by G-MW when allocation announcements are made. Allocation announcements are generally made on the 15th of each month (or the next business day), however when allocations to high reliability water shares are less than 100 per cent, allocation announcements are made on the 1st and 15th of each month (or the next business day).

The current allocation announcement and a description of likely future water availability for the remainder of the season can be sourced from: http://g-mwater.com.au/news/allocation-announcements/current.asp. Historical announcements and forecasts can be sourced from: http://g-mwater.com.au/news/allocation-announcements/archive.asp.

Additionally, G-MW publishes a seasonal allocation outlook prior to the start of each irrigation season providing a forecast for October and February allocations for the following season. The seasonal allocation outlooks are published on G-MW's website (see Media Releases). Note that in years with high water availability, only the seasonal allocation outlook may be prepared.

PART 3:
Monitoring and Future Options

9. Monitoring, evaluation, and improvement

9.1 Introduction

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

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

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

9.2 Existing monitoring programs and frameworks

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

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

9.3 Operational water delivery monitoring

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

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

Table 18: Flow monitoring in the Campaspe River catchment.

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

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

9.4 Key parameters for monitoring and evaluating ecosystem response

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

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

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

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

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

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

9.4.1 Potential monitoring gaps

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

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

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

10. Opportunities

10.1 Use of Goldfields Superpipe

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

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

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

10.2 Future use of Campaspe Weir

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

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Appendix 1: Flora and Fauna of the Campaspe River

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

Table 20: Lower Campaspe River species list.

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

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

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

E Endangered

CE Critically endangered

L Listed (threatened)

V Vulnerable

The presence of species has been ascertained through:

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

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Appendix 2: Operational Monitoring Report

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

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

Appendix 3: Summary of VEFMAP monitoring

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

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

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

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

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

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

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

Flow component	Hypotheses	Indicator(s)	Monitoring sites	Frequency	Considerations for this watering options project
Winter–spring baseflows and winter–spring freshes	• Do implemented environmental flows increase overall quantity and diversity of instream habitat?	• See conceptual model for Habitat Processes • Shallow and slow water area • Run area • Permanent pool depth and volume • Inundation of physical habitat features • Inundation of higher elevation physical habitat features • In-channel and littoral cover of macrophytes.	As above	Annually, November–April	As above
Spring–early summer bankfull flows	• Do implemented environmental flows inundate low-lying runners and anabranches to create increased slackwater habitat? • Do implemented environmental flows increase the number of fish completing larval stages?	• Area of slackwater habitat in runners and anabranches • Density of post-larval fish.	As above	Annually, November–April	As above
Spring–early summer baseflows	• Do implemented environmental flows provide appropriate conditions for spawning and larval production of 'low flow specialist' and generalist fish species? • Do implemented environmental flows maintain adequate instream habitat for adult and larval fish? • Do implemented environmental flows increase the number of fish completing larval stages?	Presence/Absence of 'low flow specialist' and generalist fish larvae • See conceptual model for Habitat Processes • Shallow and slow water area • Run area • Permanent pool depth and volume • Connectivity • Density of post-larval fish	As above	Annually, November–April	As above

Flow component	Hypotheses	Indicator(s)	Monitoring sites	Frequency	Considerations for this watering options project
Spring–early summer overbank flows	• Do implemented environmental flows inundate low-lying runners and anabranches to create increased slackwater habitat? • Do implemented environmental flows inundate floodplain areas to create increased slackwater habitat? • Do implemented environmental flows provide appropriate conditions for spawning and larval production of 'flood specialist' non-diadromous fish species? • Do implemented environmental flows increase the number of fish completing larval stages?	• Area of slackwater habitat in runners and anabranches • Area of slackwater habitat in floodplain • Presence/Absence of 'flood specialist' non-diadromous fish larvae • Density of post-larval fish.	As above	Annually, November–April	As above
Summer–autumn low flows	• Do implemented environmental flows maintain adequate instream habitat for adult and larval fish? • Do implemented environmental flows increase the number of fish completing larval stages?	• See conceptual model for Habitat Processes • Shallow and slow water area • Run area • Permanent pool depth and volume • Connectivity • Density of post-larval fish	As above	Annually, November–April	As above
Water Quality					
All components (year- round)	• No specific hypotheses	Colour, dissolved organic carbon, dissolved reactive phosphorus, electrical conductivity, total Kjeldahl nitrogen, oxidized nitrogen, pH, total phosphorus and turbidity.	Reach 2: 4 sites Reach 3: 4 sites Reach 4: 5 sites	Continuous DO, EC and temperature. Monthly physico-chemical measurements.	Dedicated monitoring program may be required, depending on the water quality variable to be tested.

*See Chee et al. (2006) for details

Appendix 4: Risk assessment framework

Risk likelihood rating

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

Risk consequence rating

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

Risk analysis matrix

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

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