2015

NORTH EAST CATCHMENT MANAGEMENT AUTHORITY

Ovens River
Environmental Water Management Plan

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EXECUTIVE SUMMARY

The Ovens River Environmental Water Management Plan (EWMP) sets out the long-term (approximately 10-year) management goal and objectives for environmental values of the lower Ovens River system. This system incorporates the Ovens River below Myrtleford, the Buffalo River below Lake Buffalo, and the King River below Lake William Hovell. The EWMP is an important part of the Victorian Environmental Water Planning Framework. It provides long-term management intentions, based on scientific information and stakeholder consultation, for both short and longer-term environmental water planning.

The EWMP's objective is to develop a ten year plan to use the Commonwealth environmental water (70ML) as well as creative (or innovative) delivery of passing flows and consumptive water, to contribute environmental benefit.

The key outcomes of the Ovens River EWMP are:

Long term management goal: The long-term environmental water management goal for the Ovens River is to:

> *Use the environmental water reserve, and water management measures, of the Ovens River, to build viable populations of iconic native fish and ensure that they are resilient.*

Ecological objectives: To achieve the long term management goal, the following ecological objectives are required to be met:

- Maintain condition of adult fish of target species;
- Maintain survival rates of juveniles of target fish species; and
- Increase / maintain production of larvae of target fish species.

The target fish species identified for the Ovens River system are Trout Cod, Macquarie Perch, and Murray Cod. These threatened large bodied fish species were chosen because of their 'iconic' status and, more importantly, because meeting their ecological needs also covers the broad ecological needs across the river ecosystem. This is due to the interconnections between habitat diversity (principally aquatic & riparian vegetation and structural habitat), invertebrates and fish populations. Microinvertebrates, macroinvertebrates, and small fish play important roles including nutrient and organic matter processing and are important in the diets of the large-bodied fish. Invertebrate populations are also important in the food chains of other fish, frogs, platypus, turtles and waterbirds. Therefore, the objectives for the large-bodied native fish are 'umbrella objectives'. Achievement of these objectives contributes to, and requires, a healthy river ecosystem.

Hydrological objectives: The hydrological objectives are recommended flow components within management control that support the native fish objectives. These flow components are:

- Summer low flows (releases of at least 20 ML/day);
- Low flow freshes (adding to an existing flow event and/or stand-alone pulses to address urgent environmental needs); and
- Flow freshes at all flows and times of the year (including through creative management of bulk water releases).

Ten year water regime principles: Due to its mostly unregulated nature and the small Commonwealth environmental water, the Ovens River flow plan is presented as a set of principles and processes, which can be used to influence how flows are set rather than a precisely specified series of planned yearly flows. These principles will guide the development of a rolling water regime plan to be implemented using a recommended adaptive management procedure. Principles to guide the development of seasonal watering plans are:

- All options should relate to meeting low flow ecological objectives;
- The 70 ML of Commonwealth environmental water is best utilised during low flow periods, particularly infilling or extending a low flow fresh;
- Environmental minimum flow rules should be revisited to allow greater discretion to both G-MW and NECMA/VEWH for its release;
- Formalise and create protocols around communications between G-MW and NECMA/VEWH for the use of bulk release water; and
- Encourage further cooperation between agencies for the delivery of consumptive water to diverters and towns.

Constraints and limitations to delivery of environmental water: The main limitation to delivery of environmental flows in the Ovens River is the precision of how it is delivered from the current infrastructure. These limitations means it is difficult to adjust the outlets for the small volumes available. In addition, restriction policies in place for the Ovens System apply to both environmental and consumptive users. The 70 ML Commonwealth environmental water entitlement has only been delivered in full for 3 of the 6 years it has been in existence (up until 2015). A return to drought conditions similar to 2006-07 would likely see a level of restriction imposed such that no allocation of the 70 ML entitlement would be available. The outlet capacity at Buffalo limits the ability to delivery larger freshes required by the system, these would need to be met naturally in both magnitude and timing.

Demonstrating outcomes: Within the context of the management goal and ecological objectives, a fish monitoring program incorporating concurrent sampling of microcrustacea and other zooplankton has been identified as important to demonstrate outcomes from environmental water management. Sampling of macroinvertebrates and monitoring of water quality were identified as providing important supplementary information on ecosystem condition. Other important monitoring actions include continuous monitoring of dissolved oxygen in the lower reaches of the river at very low flows; targeted investigations of dissolved oxygen-velocity relationships; and flow monitoring during discrete flow releases.

Knowledge gaps and recommendations: Actions recommended to help fill existing knowledge gaps include:

- Document the operations of the Hydropower scheme to understand potential limitations it may place on environmental water releases;
- Design and implement a monitoring program to determine flow losses;
- Examine options to access new environmental water;
- Assess the current consumptive demands in the system;
- Conduct original research into the ecological responses of fish to environmental water releases;
- Undertake research into what role does the Ovens River system play in the Murray-Darling Basin;

- Quantitatively assess the impacts of recreational fishing and estimate impacts of any increases; and,
- Develop a Bayesian network to assist decision-making and scenario testing for flows in the lower Ovens.

Other components: The above outcomes were developed following the process presented in the State government guidelines for river environmental water plans (DEPI 2014) and included:

- review of available relevant literature including scientific publications and departmental and consultancy reports;
- an overview of the site environment and management;
- an examination of the system hydrology and operations;
- a description of the water dependent values, including environmental, social, cultural and economic;
- a description of the current ecological condition of the site reaches and their condition trajectories;
- a risk assessment of threats to the water-dependent ecological values; and
- extensive stakeholder consultation, including one-on-one discussions and a stakeholder workshop.

1 INTRODUCTION

This Plan sets out the background information relating to flows, water dependent values in the Lower Ovens system and the flow regime required over the next ten years to maintain these values. It follows the format of the Victorian Guidelines for the development of Environmental Water Management Plans.

1.1 Purpose and Scope of the Lower Ovens EWMP

The North East Catchment Management Authority (North East CMA) has commissioned the development of the Environmental Water Management Plan (EWMP) for the regulated Ovens River system (the lower Ovens). The objective of the work is to develop a ten year plan to use the quantity of environmental water available (70ML) as well as creative (or innovative) delivery of passing flows and consumptive water, to contribute environmental benefit.

Since 2009/10 a Commonwealth environmental water entitlement of 70 ML has been available for annual delivery to the lower Ovens River. 20 ML of this entitlement is held in Lake Buffalo and 50 ML in Lake William Hovell. More recently, there has been an opportunity to add to the existing water holdings, through delivery of a bulk release drawdown from Lake Buffalo at the end of the irrigation season. For three watering years (2011/12 to 2013/14) these bulk releases have ranged from 5,000 to 8,000ML. In 2014 there was insufficient volume in Lake Buffalo at the end of the irrigation season to deliver a bulk release drawdown. Another potential source of water for environmental purposes can be generated from the creative delivery of consumptive water releases.

To date, environmental watering activities in the lower Ovens have been managed and delivered on an annual basis through Seasonal Watering Proposals developed by the North East CMA. These proposals follow recommendations from the lower Ovens River Environmental Flows study (Cottingham et al., 2008).

This EWMP for the lower Ovens River system will document, inform, and improve environmental water resource delivery outcomes in the lower Ovens through implementation of a long-term framework. Achieving this objective required the following:

- Verification of the water-dependent ecological values present in the system;
- Development of a long-term management goal for the system, based on the ecological values of the river system;
- Identification of long-term priority ecological objectives and their water requirements; and
- Identification of environmental watering actions over the ~ 10 year plan to realise the goal.

The EWMP should be reviewed after 5 and ten years of operation or if some major system operation or further major climatic change occurs.

1.2 Development Process

The EWMP was developed according to the DELWP Guidelines for EWMPs. This involved synthesising all previous information on water management in the Ovens River, and conducting discussions with operators and stakeholders to understand the operation of the system and its management. The consultation work initiated by the North East CMA during the development of the Regional Waterway Strategy was built upon through one-on-one consultations, reviews and a workshop with key stakeholders. The workshop in particular assisted the project team in identifying the range of values and threats the system faces (with regard to water dependent values) and any complementary actions that may help support better water management.

2 SITE OVERVIEW

The Ovens River catchment lies in north-east Victoria and extends from the Great Dividing Range in the south, to the Murray River in the north. It covers an area of 7,985 km^2 and is bordered by the Broken River Basin to the west and the Kiewa River Basin to the east. The topography of the Basin ranges from riverine plains near the Murray River and broad alluvial valleys around Myrtleford, to mountainous terrain and plateaux around the Great Dividing Range (GMW 2015).

2.1 Regulation in the Ovens River Catchment

The Ovens River catchment is variously described as unregulated, largely unregulated, mostly unregulated, or categorised into the unregulated upper and regulated lower Ovens. With its focus on the lower Ovens River, this document concentrates on the reaches that are affected by regulation. However, this regulation represents minor volumes in relation to the annual flows of the system. Lake William Hovell's capacity of under 13.7 GL represents less than 7% of the King River's average annual flow of 200 GL and Lake Buffalo's capacity of 24 GL represents approximately 5.5% of the Buffalo River's average annual flow of 440 GL (Peter Cottingham and Associates and Murray-Darling Freshwater Research Centre 2007). Combined, these storages can hold just over 2% of the average annual flows in the Ovens River as it passes Wangaratta (1,750 GL, PC&A and MDFRC 2007).

In this document, the lower Ovens system is described as 'mostly unregulated', unless citing descriptions provided in reference material.

2.2 Location of reaches

For river management purposes, the lower Ovens River and its two major tributaries are divided into 5 reaches: the Buffalo River below Lake Buffalo; the King River below Lake William Hovell to Moyhu; The King River from Moyhu to the Ovens River at Wangaratta; the Ovens River below Myrtleford; and, the Ovens River below Wangaratta (Figure 1).

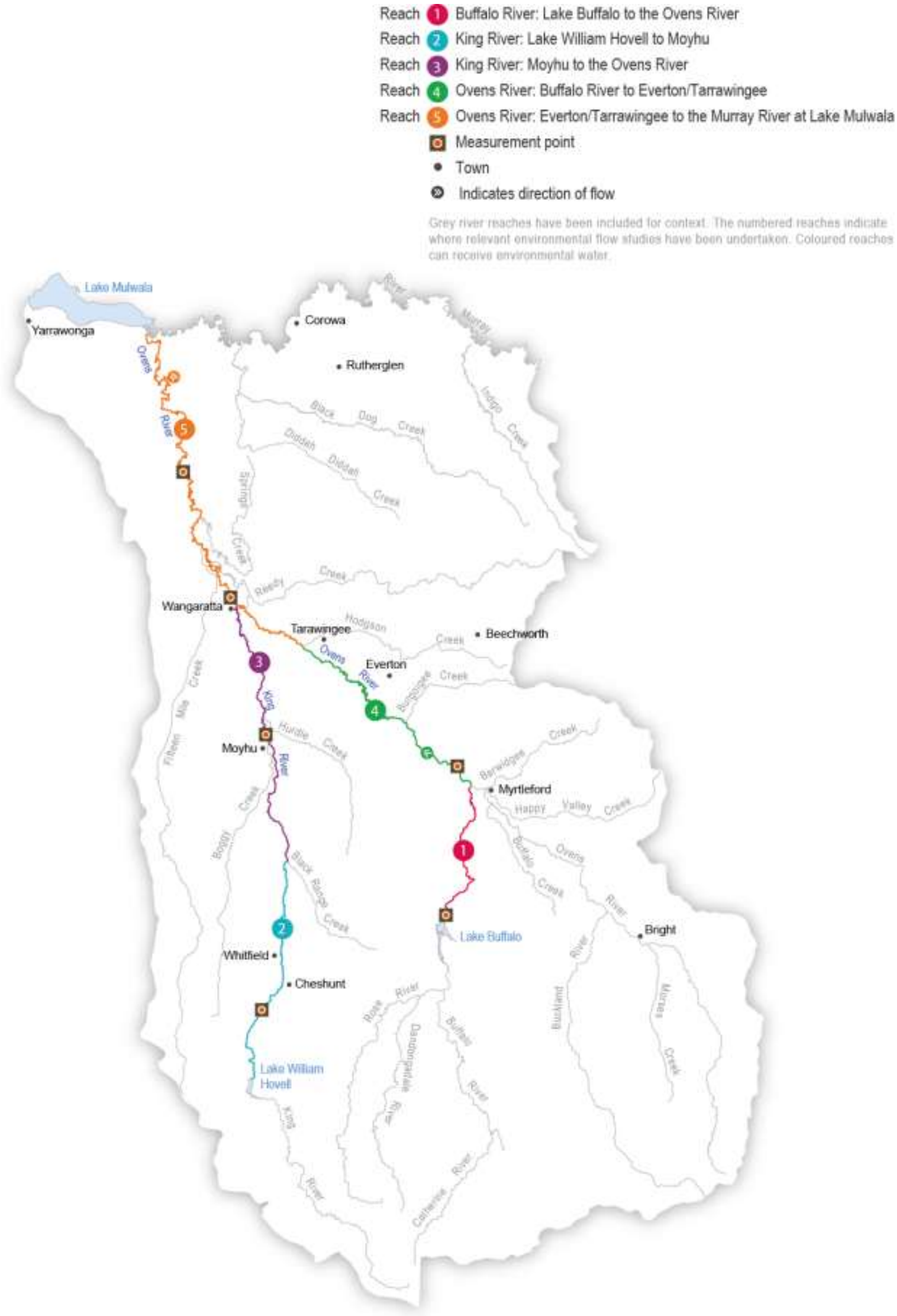

Figure 1: The Lower Ovens System (from VEWH 2015)

2.3 Catchment setting

2.3.1 Climate

Climate within the catchment reflects its topography. Mount Buffalo (elevation 1723 m ASL) in the upper, alpine area of the catchment receives an annual mean precipitation of 1855 mm. In January its mean monthly maximum temperature is approximately 20^0 Celsius and in July its mean monthly minimum temperature is -0.6^0 Celsius. In contrast, Wangaratta (elevation 150 m ASL) receives a mean annual rainfall of 636 mm, has a mean monthly maximum temperature of 31^0 Celsius in January and in July its mean monthly minimum temperature is approximately 3^0 Celsius (Bureau of Meteorology, 2015).

Three important aspects of the precipitation in the catchment are:

- the high country in the south of the catchment contributes greater run-off than the northern plains;
- in the higher elevations (above 1400 m ASL) a large proportion of the winter precipitation falls as snow and remains on the ground during winter and early spring; and
- 65 percent of the average annual precipitation occurs during winter.

As a result, stream flow is highest in winter and early spring with some of the latter flow attributable to snow-melt (GMW 2015).

The mean values for temperature and precipitation provide only a part of the relevant information for the catchment's climate. It is the variation around these means (particularly rainfall) that drives the requirements for, and availability of, water for environmental and other uses. Within the last 15 years the Ovens River has been impacted by severe drought and successive flooding. Flows in 2004-2009 during the Millennium Drought were the lowest since records began, leading extended periods of cease to flow events in Reach 5. In 2010 the Ovens system experienced a major flooding event that was subsequently followed by more significant flood events in the following two years (NECMA 2014a).

2.3.2 Reaches of the lower Ovens

Although the presence of the Lake Buffalo and Lake William Hovell storages within the upper Ovens system impose some form of regulation on the system, this regulation is minor due to the relatively small volumes able to be stored and released. The system is the largest mostly unregulated Victorian waterway entering the Murray River and the most significant in the Murray-Darling Basin. Significant environmental value is associated with the system's status as mostly unregulated, its relative intactness, near natural flow regime, and its support of a variety of threatened and endangered flora and fauna species (see Section 3).

Five reaches are recognised on the Ovens River System (Figure 1):

Reach 1. Buffalo River from Lake Buffalo to the Ovens River

The Buffalo River enters the Ovens River approximately 2 km downstream of Myrtleford. The Lake Buffalo Dam, completed in 1965, is believed to have had minimal impact on the Ovens River, although in dry periods it is likely to have impacted streamflows and river health of Reach 1. The dam is small and has little influence on large floods, although the frequency of small to medium sized flow events may have been reduced (PC&A and MDFRC 2007). Although the dam is likely to trap bed load sediments, sediment-starvation is probably not an issue as immediately downstream of the dam, tributaries such as Sandy and Long Corner Creeks enter the Buffalo River. These waterways originate from steep valley sides and would supply considerable quantities of bed load material, along with several more tributaries entering the Buffalo River further downstream. Large wood loadings are low, possibly due to historical desnagging and the lack of suitable recruits, due to the dominance of introduced riparian vegetation such as willows and blackberries (PC&A and MDFRC 2007).

The entirety of this zone was described as a confined valley zone by PC&A and MDFRC (2007) with active floodplains of the river varying from 500m to about 3km in width. Under natural conditions the floodplain in this zone was characterised by channel avulsions that would have occurred over periods of decades to centuries (PC&A and MDFRC 2007). The majority of this confined valley is now cleared for agriculture, primarily grazing.

Reach 2. King River from Lake William Hovell to Moyhu

Below Lake William Hovell, the King River flows roughly northwards through a narrow valley to the town of Moyhu. Much of the river in this reach is characterised by fertile river flats and a fast moving flows over cobble-based river bed (NECMA 2014a). This section is characterised by a meandering channel with numerous anabranches and channel cut-offs between Edi and Cheshunt (PC&A and MDFRC 2007). This reach contains many of the valley's vineyards, as well as dairy operations, cattle grazing and fodder production areas (NECMA 2014a) and has been influenced by land clearing and intensive agriculture, willow plantings for stabilisation and subsequent willow removal and levee construction leading to channel widening (PC&A and MDFRC 2007).

Reach 2 is also within the confined valley zone described by PC&A and MDFRC (2007), characterised by confined floodplains and terraces downstream of the mountain front, extending to Moyhu. The floodplain is significantly modified for agricultural production, mostly grazing. In an ecological sense this has greatly reduced the productivity of the reach and also increased the risk of contamination from grazing stock, applied fertilisers, and the physical effects of rainfall runoff from relatively poorly protected floodplain. Floodplain wetlands also appear often to be severely modified by clearing, grazing and farm watering (Cottingham et al. 2001). Floodplain connectivity has been affected by the presence of levees in reach 2.

Reach 3. King River from Moyhu to the Ovens River

Below Moyhu, the King River channel becomes increasingly sinuous with many anabranches and some avulsions (NECMA 2014a) and the bed material becomes finer (PC&A and MDFRC 2007). There is a particularly pronounced transition where the stream changes abruptly from gravel to a sand bed stream over a few kilometres between Edi Cutting and Moyhu (PC&A and MDFRC 2007).

Described by PC&A and MDFRC (2007) as an upper anabranching reach and by Schumm et al. (1996, in PC&A and MDFRC 2007) as a plains region of alluvial fans and high terraces, the floodplain in this reach widens dramatically below Moyhu, opening out to an unconfined, expansive floodplain. The floodplain in this reach is almost entirely cleared for agriculture, predominantly cattle grazing with occasional vineyards (NECMA 2014a). Cottingham et al. (2001) concluded that the floodplain connectivity of the lower King River is largely unimpacted by flow regulation, but greatly reduced by the construction of levees.

Reach 4. Ovens River from the Buffalo River to Everton/Tarrawingee

The river transitions from a bedrock controlled channel in the cleared foothills, through a gravel bed to a sandy bed with many anabranching channels. The channel is presently in recovery mode following expansion related to factors such as: dredging, sediment extraction and vegetation removal (Earth Tech 2007, in PC&A and MDFRC 2007).

Similar to Reach 2, the floodplains of Reach 4 are significantly modified for agriculture (mostly grazing), greatly reducing the ecological productivity of the reach and also increasing the risk of agricultural contamination and increased runoff impacts from the poorly protected floodplain. Floodplain connectivity has been affected by the presence of levees in reach 4, and floodplain wetlands appear to be severely modified by clearing, grazing and farm watering (Cottingham et al. 2001).

Reach 5. Ovens River from Everton/Tarrawingee to the Murray River at Lake Mulwala

The Ovens River, downstream of Wangaratta, is a highly sinuous anabranching river (PC&A and MDFRC 2007). Relative to other reaches, the channel has particularly high bed diversity, largely in a natural state, with deep pools common, medium to high large-wood loadings and largely intact native riparian vegetation (PC&A and MDFRC 2007).

This reach is particularly important for supporting high priority threatened native fish species. It is also the reach that is most threatened by stressors associated with very low summer flows. Low flows resulted in isolated pools which can have poor water quality (especially low dissolved oxygen levels) and crowed conditions resulting in fish to be stressed or suffer increased mortality.

The greatest threat to bed diversity is sand inputs from upstream avulsions (Reedy and Three Mile Creeks), which are likely to continue in the future (PC&A and MDFRC 2007). Significant accumulations of sand deposits are predicted by De Rose et al. (2005) in the lower reaches of the Ovens River potentially smothering bed habitat. Bank erosion was identified as a dominant source of sediment in the mid-lower Ovens River, suggesting that more effective riparian management should be a priority in mid-reaches (e.g. Reach 4) for reducing loads and improving water quality, particularly where riparian cover is poor (De Rose et al. 2005).

The floodplain in this reach is in a sound functional condition and, in combination with the largely unaltered flow pattern, has resulted in a healthy reach of river ecosystem – and one which is able to contribute to other systems in the region (Cottingham et al. 2001).

Close to Wangaratta, the floodplain is in similar condition to reaches 2 and 4. However, further downstream levees become less obtrusive, land use much less intense, and floodplain vegetation becomes less modified, denser, and more widespread over the floodplain. Significant proportions of the floodplain are inundated most years in winter/spring (Cottingham et al. 2001).

2.4 Land status and management

Land Status

This EWMP focuses on environmental watering within the main channel of the lower Ovens River system. Accordingly, the only relevant land for consideration for this report is the immediate riparian zone. The majority of this land below Wangaratta, specifically from Killawarra to the Murray River is publicly-owned and under Parks Victoria management within the Warby-Ovens National Park. Upstream it is largely Crown Land, and often subject to private grazing leases.

Environmental Water Management

There are several agencies directly involved in environmental water management in Victoria, and other agencies, such as public land managers, play an important role in facilitating the delivery of environmental watering outcomes. Table 1 summarises the agencies and groups that have involvement in environmental water management in the Ovens River.

Table 1: Agencies and groups involved in Ovens River environmental water management

Agency/group	Responsibilities/involvement
Department of Environment, Land, Water and Planning (DELWP) (formerly Department of Environment and Primary Industries (DEPI)	Develop state policy on water resource management and waterway management approved by the Minister for Water and Minister for Environment and Climate Change. Develop state policy for the management of environmental water in regulated and unregulated systems. Act on behalf of the Minister for Environment, Climate Change and Water to maintain oversight of the VEWH and waterway managers (in their role as environmental water managers). Manage the water allocation and entitlements framework.
Victorian Environmental Water Holder(VEWH)	Make decisions about the most effective use of the Water Holdings, including use, trade and carryover. Authorise waterway managers to implement watering decisions. Liaise with other water holders to ensure coordinated use of all sources of environmental water. Publicly communicate environmental watering decisions and outcomes.
Commonwealth Environmental Water Holder (CEWH)	Make decisions about the use of Commonwealth water holdings, including providing water to the VEWH for use in Victoria. Liaise with the VEWH to ensure coordinated use of environmental water in Victoria. Report on management of Commonwealth water holdings.
Murray-Darling Basin Authority (MDBA)	Implementation of the Murray-Darling Basin Plan - the Basin Plan sets legal limits on the amount of surface water and groundwater that can be taken from the Basin from 1 July 2019 onwards. Integration of Basin wide water resource management. Manager of The Living Murray water entitlements.
North East Catchment Authority (North	Identify regional priorities for environmental water management in regional Waterway Strategies.

Agency/group	Responsibilities/involvement
East CMA) Waterway Manager	In consultation with the community assess water regime requirements of priority rivers and wetlands to identify environmental watering needs to meet agreed objectives identify opportunities for, and implement, environmental works to use environmental water more efficiently. Propose annual environmental watering actions to the VEWH and implement the VEWH environmental watering decisions. Provide critical input to management of other types of environmental water (passing flows management, above cap water) report on environmental water management activities undertaken.
Goulburn Murray Water (GMW)	Water Corporation – Storage Manager and Resource Manager. Work with the VEWH and waterway managers in planning for the delivery of environmental water to maximise environmental outcomes. Operate water supply infrastructure such as dams and irrigation distribution systems to deliver environmental water. Ensure the provision of environmental minimum flows and compliance with management of diversion.
Parks Victoria	Land Manager of some areas of the system. Where agreed, participate in the periodic review of relevant EWMPs. Manage and report on other relevant site and catchment management and risk management actions required due to the implementation of environmental water.
Traditional Owners/ Community Groups	The delivery of environmental water is likely to provide other benefits that depend on the condition of our waterways, such as supporting social and cultural values.

2.5 Environmental water sources

A total of 70ML of Commonwealth environmental water is available in the lower Ovens River. Lake Buffalo on the Buffalo River holds 20ML of this entitlement and 50ML is held in Lake William Hovell on the King River (Table 2). This environmental entitlement has been delivered to the system since 2009-10 (see Section 3).

In recent years there has been an opportunity to complement the water holdings with delivery of a bulk water transfer to the Murray System from Lake Buffalo at the end of the irrigation season. The North East CMA has worked with Goulburn-Murray Water since 2012 to design release patterns for these end of season bulk releases that mimic natural flow pulses. Availability and volume of bulk releases is dependent on seasonal conditions. Environmental minimum flows and unregulated flows also have a significant effect on the flow regime of the Ovens System. Alternative delivery options for bulk releases and environmental minimum flows may provide new sources of water for environmental benefits but these are yet to be designed, agreed and tested. One proposal is to store and pulse the release of environmental minimum flows allocation to provide for flow freshes when required in the system, rather than a constant release amount.

Table 2: Sources of the Environmental Water Reserve for the Ovens System.

Environmental Water	Agency	Description	Conditions
Water Holding	CEWO	Up to 20 ML/yr in Lake Buffalo.	Only available while lake is not spilling.
Water Holding	CEWO	Up to 50 ML/yr in Lake William Hovell.	Only available while lake is not spilling.
Environmental Minimum Flows	G-MW	From Bulk Water Entitlement: (a) in the King River between Lake William Hovell and Cheshunt: (i) during the months of November to May inclusive, the lower of 20 ML per day or the natural flow generated in all of the catchment upstream of Cheshunt (ii) during the months of June to October inclusive, the lower of 30 ML per day or the natural flow generated in all of the catchment upstream of Cheshunt (b) in the King River between Cheshunt and the Ovens River confluence (i) during the months of November to May inclusive, the lower of 40 ML per day or the natural flow generated in all of the King River catchment (ii) during the months of June to October inclusive, the lower of 20 ML per day or the natural flow generated in all of the King River (c) in the Buffalo River between Lake Buffalo and the Ovens River confluence during the months of November to May inclusive, the lower of 60 ML per day or the natural flow generated in all of the Buffalo River catchment (d) in the Ovens River between the Buffalo River confluence and the King River confluence during the months of November to May inclusive, the lower of 154 ML per day or the natural flow generated in all of the Ovens River catchment (e) in the Ovens River downstream of King River confluence (iii) during the months of November to May inclusive, the lower of 140 ML per day or the natural flow generated in all of the Ovens River catchment	Minimum flow requirements for reaches below the two storages when the Ovens System is in a regulated state.

Environmental Water	Agency	Description	Conditions
		(iv) during the months of June to October inclusive, the lower of 50 ML per day or the natural flow generated in all of the Ovens River catchment	
Unregulated flows		Flows during the period when Lake Buffalo and Lake William Hovell are not regulating system inflows.	Available when all the Ovens System is in an unregulated state. The system is often in this state for approximately half the year.
Bulk release drawdown	G-MW	Released from Lake Buffalo. In the 2011/12, 2012/13 and 2013/14 water years, this volume has been approximately 8,000 ML, 5,000 ML and 4,200 ML, respectively.	Available at the end of the irrigation season in recent years though total volume varies. G-WM advises the CMA on availability towards end of season. Prediction of volume is difficult.

2.6 Related agreements, policy, plans and activities

Policies, strategies, plans and activities, including relevant state, national and international legislation and agreements that are specifically relevant to the environmental water management of the lower Ovens River include:

- State legislation – of particular relevance are the *Water Act 1989, Catchment and Land Protection (CaLP) Act 1994, Flora and Fauna Guarantee (FFG) Act 1988, Aboriginal Heritage Act 2006, Traditional Owner Settlement Act 2010, Conservation, Forests and Lands Act 1987* and *Crown Land (Reserves) Act 1978.*
- National legislation including *the Water Act 2007 and Water Amendment Act 2008 (Cth), the Environment Protection and Biodiversity Conservation (EPBC) Act 1999* and the *Native Title Act 1993*).
- Murray-Darling Basin Authority policies (e.g. The Living Murray Initiative and the Murray-Darling Basin Plan).
- The Commonwealth Environmental Water Holder (CEWH) is constituted under the Water Act 2007 (Cwlth). The CEWH (through its Office – CEWO) manages all Commonwealth Water Holdings including the environmental entitlement of 70 ML of the lower Ovens system as well as access to other water sources. This entitlement is a small proportion of the overall flow in the lower Ovens system, reflecting the mostly unregulated nature of the system.
- VEWH Seasonal Watering Plan: guides environmental water management across the Victoria and provides information to program partners, stakeholders and the community.

Strategies, programs and projects relevant to the lower Ovens EWMP include:

- Victorian Waterway Management Strategy 2013 (VWMS) – this strategy outlines the direction for the Victorian Government's investment over an eight year period (beginning in 2012/13). The overarching management objective is to maintain or improve the environmental condition of waterways to support environmental, social, cultural and economic values (DEPI 2013a).
- 2014-2022 - North East Waterway Strategy – this regional strategy is an action out of the VWMS and was developed to ensure the region's waterways are valued, healthy and well-managed. It is designed to encourage and support people who are making decisions about waterway management activities in the North East. Specifically, it considers environmental, economic, cultural and social factors and highlights stressors and challenges in the region that may impact on waterway health. North East Waterway Strategy has identified the Ovens as a high priority because of its high value significant environmental values present.
- 2014 North East Regional Catchment Strategy (RCS) – the RCS includes a range of 20 and 6 year objectives and actions that include a 20 year high level objective maintaining and enhancing the health and condition of the region's land, water and biodiversity resources and their long-term productivity.

3 HYDROLOGY AND SYSTEM OPERATIONS

Although the Ovens system is mostly unregulated, operations at Lake William Hovell and Lake Buffalo can often be complex to meet the requirements of downstream primary entitlement holders, stock and domestic requirements, as well as deliver environmental minimum passing flows and the Commonwealth Environmental Water Holder (CEWH) requirements. Restrictions to supplies may be imposed on primary entitlement holders where inflows received and volumes held are insufficient to meet demand.

The water stored in Lake Buffalo is used to supplement flows in the Buffalo and Ovens Rivers for irrigation and urban water supply. Lake William Hovell supplies water for irrigated crops, vineyards and grazing properties along the King River from Cheshunt to Wangaratta.

The way water is managed and released from these two storages is influenced by the operation of the hydro-electricity station at Lake William Hovell, bulk draw down of water at either storage for maintenance reasons, or flood routing at Lake Buffalo due to its gated spillway.

3.1 River hydrology

The Ovens River is largely perennial with flows maintained throughout summer in the upper reaches of the Ovens, Buffalo, and King Rivers and their unregulated tributaries. Spring, summer and autumn flows are supplemented in the lower reaches through releases from Lake Buffalo and Lake William Hovell to supply water to diverters (irrigation and stock use), town water supply and also to meet environmental minimum flows (similar to passing flows in other systems). It is during these warmer months where most differences can be inferred between the natural and regulated flow regimes. There is limited authoritative work that specifically characterises the natural flow regime and contrasts this against low flow regulated flow regimes.

Flow in the Ovens System can be highly variable throughout the year. Snow melt and higher rainfall in the mountainous regions can also often provide high winter and spring flows. Figures 2 and 3 compare the historic daily flow patterns for the King River below Lake William Hovell and the Buffalo River below Lake Buffalo. Both figures also show the streamflows at Wangaratta to allow comparison of flow magnitudes and frequencies between upstream and downstream reaches.

The flow regime of the Ovens, King and Buffalo can be influenced during low flows by the presence and operation of Lake Buffalo and Lake William Hovell, and by the progressive extraction of water for stock and domestic, irrigation and town water supply (Cottingham et al. 2008). The continuous release of consumptive water from storage can limit flow variability, and can be restricted during dry periods. Cottingham et al. (2008) reports the Ovens River as predominantly a losing stream (meaning that seepage and evaporation will result in water lost from the river) from approximately 6 km downstream of Myrtleford during warm and dry periods. The King River downstream of William Hovell can also be considered a losing stream during dry periods (G-MW 2015, pers. comm.).

Average annual streamflow in the study area ranges from approximately 194 GL in the King River (site 403228), to approximately 365 GL in the Buffalo River (site 403220), 1050 GL in the Ovens River at Rocky Point (site 403230) and 1,076 GL in the Ovens River below Wangaratta (site 403200). These figures include both the millennium drought of the 2000’s and then the significant floods of 2010 and 2011[1]

[1] http://data.water.vic.gov.au/monitoring.htm

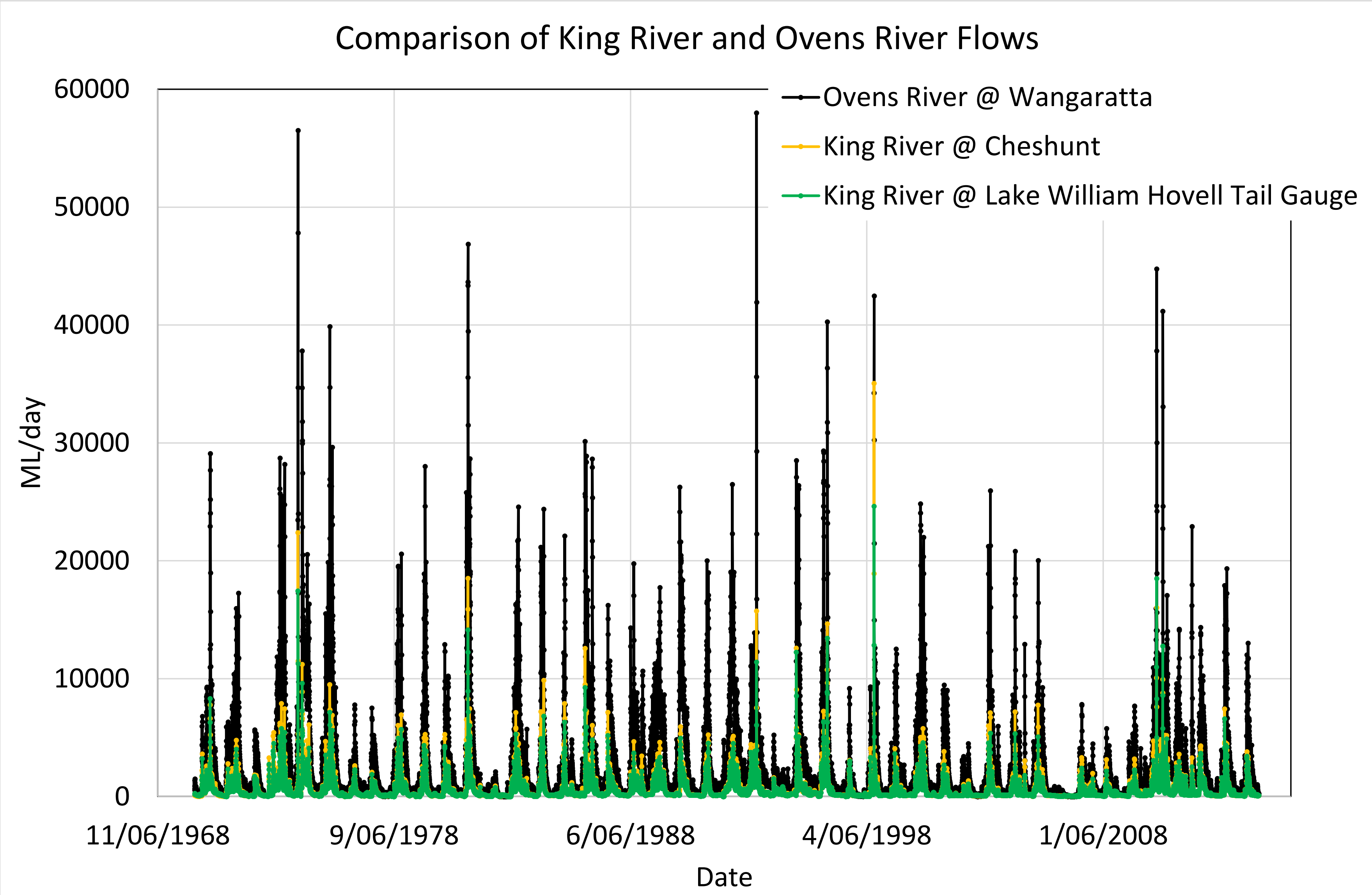

Figure 2: Comparison of streamflows showing the relative magnitude and frequencies between key monitoring sites for King and Ovens Rivers.

Flow in all reaches is virtually perennial. The flow record (1970-2004) shows very small percentage of days with zero flows (Figure 3).

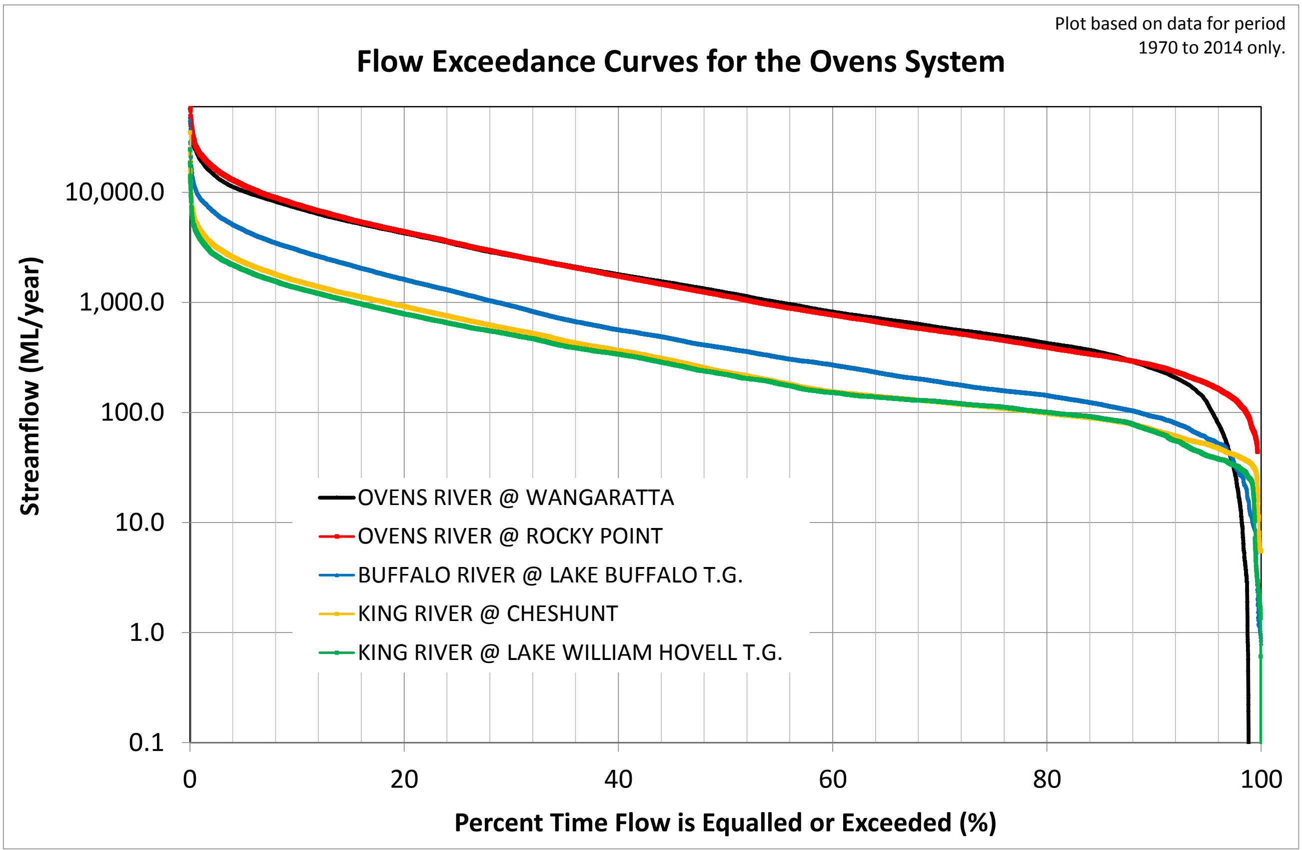

Figure 3: Exceedance curves for flow at key gauging locations on the Ovens System.

In general, Lakes William Hovell and Buffalo capture small to medium sized flow events in winter and spring and subsequently release this stored water to meet downstream demand in summer and autumn. River flows below the dams can therefore be higher than natural over the summer and autumn period (Cottingham et al. 2008). This modification to flow regime is most pronounced during dry years, although entitlement restrictions during drought can still result in low flows.

Environmental minimum flows also exist for each river reach and are prescribed by the Bulk Entitlement provisions for the Ovens system (DSE, 2011, Bulk Entitlement (Ovens System Goulburn-Murray Water) Conversion Order 2004 – Consolidated Version). These environmental minimum flows are based on the 95% exceedance flows, or natural, and were originally derived by the work of Cottingham et al. (2001).

The operation of Lakes Buffalo and William-Hovell does not materially affect the magnitude of floods in the Ovens and King Rivers, but does cause a slight delay in the flood peak if inflows arrive when the dams are empty (or contain significant air space). The effective outlet capacities for both Lake Buffalo and Lake William Hovell are about 500 to 600 ML/d (the actual outlet capacities are described further in subsequent sections). When comparing the ability to regulate flows via the outlet to the magnitude of unregulated flows that can spill over the reservoirs, it is easy to draw this same conclusion.

Overall, the effect of regulation and diversions on the flow regime across the study area is mainly confined to low flow periods during dry and warmer months (Table 3; Cottingham et al. 2008).

Low flows result in in-channel depth reductions of in the order of tens of centimetres (Cottingham et al. 2001; 2008). These reductions can isolate pools (decreased connectivity) and reduce mixing (decreased water quality) which are both critical factors in the instream ecology of the system (King 2004a and b; King et al. 2009; Brookes et al. 2009; Broadhurst et al. 2013; Kingsford et al. 2014; Koehn et al. 2014). Depending on timing and delivery (or configuration), regulated flows have some potential to provide environmental benefit. Even modest changes to regulated flow regimes can have a positive effect on fish populations (Rolls and Arthington 2014).

Very low flows can isolate sections of the system and prevent fish migrating along the system to feed, find habitat or mates and to spawn. Flow freshes allow a physical connection between the reaches of the system and between the Ovens and Murray systems but allowing fish to move across riffles and bars in the system. Therefore flow freshes will have an important contribution to ecosystem health and biodiversity in both the Ovens and the Murray Rivers.

Table 3: Comparison of compliance of the summer-autumn current and natural flow regime with environmental flow recommendations (Source: Cottingham et al. 2008).

Reach	Flow Component	Magnitude	Frequency	Duration	Ratio current:natural
1	Low flow	Within range of 70 or natural (whichever is lower) and 680 ML/d or natural (whichever is higher), with absolute minimum of 10 ML/d (no cease to flow)	Continuous	Continuous	99% (min 10 ML/day) 100% (10 – 90 %-ile range)
2	Low flow	Within range of 60 or natural (whichever is lower) and 415 ML/d or natural (whichever is higher), with absolute minimum of 10 ML/d (no cease to flow)	Continuous	Continuous	95% (min 10 ML/day) 97% (10 – 90 %-ile range)
3	Low flow	Within range of 26 or natural (whichever is lower) and 985 ML/d or natural (whichever is higher), with absolute minimum of 10 ML/d (no cease to flow)	Continuous	Continuous	95% (min 10 ML/day) 97% (10 – 90 %-ile range)
4	Low flow	170 or natural, absolute minimum of 10 ML/day	95% of years	Continuous	100% (min 10 ML/day); 97% (10 – 90 %-ile range)
	Low flow fresh	≥ 650	2 per year	3 days	
5	Low flow	Lesser of 130 or natural	Continuous	Continuous	94%
	Low flow	> 250	Continuous	Continuous	75%
	Low flow fresh	130 - 260	4 per year	3 days	100%

The Ovens system is relatively well gauged and monitored to track these flow changes. The key sites for operational and compliance monitoring are listed in Table 4.

Table 4: Streamflow gauging sites for the Ovens System.

Site No.	**Site Name**	**Comment**
403220	Buffalo River downstream of Lake Buffalo	Reach 1 - Measures regulated releases and unregulated spills from Lake Buffalo. Also used for the delivery of minimum environmental passing flows.
403227	King River @ Cheshunt	Reach 2 – Used to measure releases from Lake William Hovell. Also used for compliance with environmental minimum flows.
403223	King River @ Docker Road	Reach 3 - Same as site 403227 but used for compliance monitoring for reach 3.
403230	Ovens River @ Rocky Point	Reach 4 – compliance monitoring gauge downstream of the confluence with the Buffalo River.
403200	Ovens River @ Wangaratta	Reach 5 – a key site for compliance monitoring. Also used for analysis of streamflows at Wangaratta below the confluence of the King River.
403241	Ovens River @ Peechelba	Reach 5 – an additional compliance monitoring site and the most downstream Ovens System monitoring site prior to the confluence with the River Murray.

3.2 System operations – history of use

3.2.1 Water management and delivery

Water management agencies involved with the Ovens System are Goulburn-Murray Water which own and operate the majority of instream assets (including Lakes Buffalo and William Hovell), North East Water and the North East Catchment Management Authority. Other significant stakeholders include the Victorian and Commonwealth Environmental Water Holders and several local government areas (e.g. Wangaratta Rural City Council).

The Bulk Entitlement (Ovens System – Goulburn-Murray Water) Conversion Order 2004 (Consolidated version 2011) describes the primary entitlements to water along with obligations to provide environmental minimum flows. Table 5 summarises these entitlement arrangements.

Table 5: Summary of primary entitlement holders in the Ovens System.

Description	High Reliability (ML)	Low Reliability (ML)
Ovens R diverters d/s Buffalo R confluence (zone 9A)	11,554.1	5,193.8
Buffalo R diverters d/s Lake Buffalo (zone 9A)	3,901.0	1,864.0
King R diverters d/s Lake William Hovell (zone 9B)	10,993.4	5,429.4
CEWH[2]	70	-

The Bulk Entitlement (Ovens System – Moyhu, Oxley and Wangaratta – North East Water) Conversion Order 2004 (Consolidated version 2011) also provides detail on the entitlement to water for North East Water for the provision of water supply (see Table 6).

Table 6: Summary of annual entitlement volumes for North East Water.

Town	Annual Entitlement Volume (ML)	Allowed Rate of Supply (ML/d)
Wangaratta.	7720	79
Oxley	66	1.1
Moyhu	46	1.5

The Commonwealth Environmental Water Office holds an environmental entitlement of 70 ML, with a long-term average yield of 67 ML[3].

All primary entitlement holders are subject to a restriction policy administered by G-MW. This means that full entitlement may not be available in all years. CEWH volumes are also subject to restrictions during dry years and so natural flow conditions may become more relevant in dry years.

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[2] (www.environment.gov.au/water/cewo/about/water-holdings)

[3] (www.environment.gov.au/water/cewo/about/water-holdings [accessed February 2015]).

Operation of Lake Buffalo

Lake Buffalo is located on the Buffalo River approximately 20 km south of Myrtleford (Figure 1). Construction of the dam was completed in 1965. It has a capacity of 24,000 ML and a catchment area of approximately 1,060 km^2. At full supply level (FSL) the lake has a surface area of approximately 340 hectares and water surface elevation of 264.4 m AHD. The dam has a height of 31 metres and creates a relatively deep impoundment. There are two spillways; an Ogee Crested concrete gated spillway with a design capacity of 110,000 ML/d and an uncontrolled earthen chute with a design capacity of 61,000 ML/d. The dam has a dead storage of 5,000 ML which cannot be accessed by gravity drawdown (Cottingham et al. 2001 & www.g-mwater.com.au/water-resources/catchments/ovensbasin, accessed February 2015).

The volume of the storage is small compared to the annual average river flow of 365 GL of the Buffalo River. The dam thus has little influence on the total annual river flow volumes. As an example of the comparatively small storage, the inflow of 54,000 ML/d that occurred in 1993 would have filled the dam from empty in approximately 12 hours.

Releases from the dam can be made via either three mechanical gates or two gate valve arrangements. This allows regulation of flows at varying water levels. The outlet capacities can vary depending on lake water level, but can be as high as a total of 850 ML/d.

Summer flows (typically between 150 – 200 ML/d) are released to meet irrigation demand and for water supply requirements for Wangaratta. Historically, supplementary flows of around 300 ML/d for 3-4 weeks were made for the River Murray if additional resources are required. These operations are now given the term of "bulk water releases" or "drawdown".

G-MW aim to draw the storage down to about 13,000 ML by early May each year. If entitlement holder demand is not sufficient to do this, G-MW may reduce levels via delivery of a "bulk water release". These types of operational releases are now routinely discussed with NECMA. The goodwill offered by G-MW in seeking guidance on how best to deliver the bulk water release is a leading example for the Victorian water industry. The objective of consultations with NECMA is usually to maximise the environmental benefit of the bulk release (within volume and time constraints). However, there probably remains some benefit of formalising these discussions.

After about May, inflow to the lake gradually fills the lake (assuming it is greater than outflow). When full, inflow surplus to storage capacity spills. The primary operational objective during this period is to ensure that the storage is full by mid-November. After this time, demand may equal or even exceed inflows under dry conditions. G-MW routinely monitor inflows and water use during the filling season and into the warmer months. Rules exist to impose restrictions on entitlement holders under dry conditions.

Overall, Cottingham et al. (2001) reports that the major effect of Lake Buffalo on downstream flow regime in Reaches 1 and 4 may be characterised as:

- Flow in the Buffalo River remains relatively constant between February and April due to the presence of mostly regulated flows rather than fluctuating at low volumes (e.g. flow of 600 ML/d versus 40-50 ML/d naturally). At the stream gauge below Lake Buffalo, the difference between a flow of 40 ML/d and 600 ML/d is 0.5 m (0.5 m versus 1.0 m, respectively).
- Releases from the dam are reduced from May until the dam fills to 13,690 ML (after drawing down in April to about 6000 ML). This situation may persist from one week to a month, depending on inflow volume. The effect is generally that releases are in the order of tens of ML/d rather than hundreds of ML/d (almost the reverse of the summer effect).
- Discharge generally falls in October as the dam fills by another 10,310 ML to its capacity of 24,000 ML depending on catchment inflows (usually within a few weeks).

Operation of Lake William Hovell

Lake William Hovell is located on the King River approximately 18 kilometres south of Cheshunt. The dam was completed in 1973, has a capacity of 13,700 ML and a surface area of 113 hectares at FSL. The lake is supplied by a catchment area of 331 km^2. The height of the main dam is 33 metres, has an FSL of 408.1 m AHD and incorporates a free-flow overfall spillway with a capacity of 97,900 ML/d. The lake has a dead storage volume of 1,000 ML (Cottingham et al. 2001 and www.g-mwater.com.au/water-resources/catchments/ovensbasin, accessed February 2015).

The storage usually fills during the wettest months of August and September each year. Water is released all year round to meet minimum environmental flow requirements and stock and domestic demands. Most of the regulated releases occur over summer and autumn. There currently exist no storage targets for Lake William Hovell and releases are usually only made to draw down the storage when volumes exceed 8,000 ML.

G-MW make an estimate of probable irrigation demand in November and subsequent months of each year. Lake William Hovell can also be used to supplement urban water supplies on the King River and also the Ovens River.

Water can be released via two outlets at different levels, each with a capacity of 300 ML/d. Water can also be released via a mini hydro-electric power station which also has a maximum capacity of 520 ML/d. Therefore, the maximum flow that can be released when the dam is not spilling is 520 ML/d under current operations.

The 1.6 MW power station is operated remotely by PacificHydro and requires a minimum flow of 120 ML/d to operate. Management rules are in place such that the power station can draw on water when levels in the dam are within 200 mm of FSL, potentially varying flows from 120 to 480 ML/d over short time periods. Indeed, the mode of operation is to operate at maximum capacity as much as possible. This means that a release of around 500 ML/d is maintained until levels within the lake reduce to 200 mm below FSL and then is shut off, or reduced to the minimum rate of around 120ML/d. Inflows are then allowed to accumulate within the storage to build levels within the 200 mm of FSL range and operations commence again (Andrew Shields, pers. comm. 2015). The maximum change in discharge from the dam may vary water levels in the river immediately downstream of the dam by up to 35 cm, although fluctuations are typically in the order of 10 cm (Cottingham et al. 2001). The times when the power station can affect its 80 mm fluctuations are quite limited, and do not generally coincide with the irrigation season. It is also worth noting that power generation is currently most profitable by day during peak rates, and so flows are usually higher by day.

Cottingham et al. (2001) surmise that the effects of Lake William Hovell on flows in Reaches 2 and 3 of the King and Ovens Rivers is simpler than for Lake Buffalo, including:

- Augmented summer flows from January – from tens of ML/d naturally to maximum of 140 ML/d. This equates to tens of centimetre difference in stage at the dam gauge;
- The lower river used to dry out on occasion in summer (e.g. at Moyhu), but now flows year-round;
- Flows from the dam are reduced to a minimum (30 ML/d) at the end of April while storage is filled. The result is a sudden period of low flow for a few weeks until the dam is filled.

3.2.2 Environmental watering

An explanation of water sources which contributes to the EWR is summarised in Table 7.

Table 7: Sources of EWR for the Ovens System (adapted from NECMA, 2014).

Description	**Volume (ML)**	**Comment**
CEWH product	70	This water is owned by the Commonwealth and is incorporated into the seasonal water plan upon advice by NECMA and VEWH.
Unregulated flows	N/A	Inclusive of all flows that naturally occur in the river system, spill from upstream reservoirs or are released for operational reasons to maintain target curves.
Environmental minimum flows	Rules described in the Ovens BE	These passing flows are calculated either daily or weekly managed by GMW.
Operational releases	Variable	These could be in the form of bulk drawdown releases or cooperative arrangements put in place with regulated releases for other entitlement holders.

Planning for EWR delivery occurs between NECMA and VEWH with G-MW acting as a key stakeholder. The CEWO works with the VEWH and its CMA partners for the delivery of its water.

There are a number of unique challenges in providing long-term environmental water planning in the Ovens System. These challenges are:

- the small volumes of the water holdings (only 70 ML of Commonwealth environmental water);
- the mostly unregulated nature of the Ovens System and relatively small outlet capacities of storages (meaning that operation of the two storages may only have meaningful impact under particular low flow scenarios);
- limited capacity to store large volumes of water and no capacity to carryover regulated environmental water because of the relatively small volumes held in Lakes Buffalo and William Hovell; and,
- the difficultly in predicting operational requirements such as the bulk release drawdown of storages at the end of the irrigation season.

In response to this operating context, NECMA uses a seasonally adaptive approach to environmental water planning (seen for example in NECMA 2014/15 seasonal watering proposal). This identifies priorities for environmental watering based on the recommended flow components and environmental objectives for the system at the beginning of the water year. Timing of delivery needs to be flexible to respond to unfolding climatic scenarios.

Once planning has been established, these plans are operationalised by G-MW and integrated into its other broad operational responsibilities.

Because the bulk of the EWR for the Ovens system is prescribed in the Ovens Bulk Entitlement (as environmental minimum flows), delivery of environmental water does not require the day to day input from NECMA (or VEWH or CEWO), but rather the monitoring of conditions so that opportunities for additional water can best be utilised.

Opportunities for additional environmental water are limited but can be summarised as follows:

- Review consumptive entitlement arrangements to determine what "slack" exists, particularly in the context of changing land use and agricultural practices. An analysis of projected demands should be made; and,
- Formalised coordination between G-MW and NECMA to program releases of operational and consumptive water to maximise environmental benefit. A Memorandum of Understanding might be sufficient, though it would be preferable to have cooperation arrangements codified within management arrangements. Two forms of water are considered to be available to benefit the environment:
    1. Bulk water draw down volumes; and
    2. The routine delivery of consumptive water or transfers. For instance, the environmental minimum flows allocation could be stored and released as a pulse to provide for flow freshes when required in the system, rather than a constant release amount (an accumulation rule).

4 WATER DEPENDENT VALUES

4.1 Environmental values

The lower Ovens has high ecological value for a number of reasons, including:

- its listing as a Heritage River (the lower reaches, from Killawarra to Lake Mulwala) under the Victorian *Heritage Rivers Act* (1992);
- its status as one of the last largely unregulated rivers in the MDB and consequent importance as a reference for assessment of other lowland rivers in the region;
- generation of approximately 6 percent of runoff in the MDB, the importance of which is amplified by its mostly unregulated delivery to the Murray River; and
- its habitat diversity, biological diversity, and connectivity with the Murray River. With high natural flows and relatively good water quality, the Ovens River makes a vital contribution to the Murray River system as a whole and brings life to iconic Murray sites such as the Barmah-Millewa Forest (Environment Victoria 2007).

The only discretionary volume of environmental water is 70 ML available as part of CEWH holdings. Although other forms of environmental water exist (in the form of unregulated and environmental minimum flows), this description focuses on the water dependent values within the stream, most commensurate with the scale of the sources of environmental water. Therefore, the significance of many species, plant and animal communities, and social and economic values associated with the floodplain and wetlands of the lower Ovens are largely out of scope.

All the reaches of the lower Ovens are rated as being in 'moderate' condition using the Index of Stream Condition (ISC; DEPI 2013) (Table 8). The hydrology sub-index in all reaches received a low score of 4 or 5, primarily due to their proximity to the Lake William Hovell and Lake Buffalo dams.

Table 8: 2010 ISC reach numbers, scores and ratings for reaches of the lower Ovens*

Lower Ovens Reach	ISC Reach	ISC sub-indices					ISC score	Condition rating
		Hydrology	Physical form	Streamside zone	Water quality	Aquatic life		
1	33	4	6	7	-	6	24	Moderate
2	22	4	7	7		8	28	Moderate
	23	4	7	7		6	27	Moderate
	24	4	7	8	8	6	30	Moderate
3	21	4	9	7	7		31	Moderate
4	4	5	7	7	8	7	32	Moderate
5	1	5	7	8	9	4	29	Moderate
	2	5	7	9		7	31	Moderate
	3	5	9	7			32	Moderate

*The final ISC score is a weighted mean of the five sub-indices

Interestingly, the most downstream ISC reach (ISC Reach 1 from Peechelba to the Murray River) received the lowest score of all reaches for aquatic life. The aquatic life sub-index is based on macroinvertebrate assemblages. The lower sections of the Ovens River are characterised by a deeply incised channel with few macrophytes, sandy to gravel substrate and steep banks. These conditions are not typical of natural lowland rivers in the region and it has been suggested that lower than expected scores for macroinvertebrates may be more indicative of the uniqueness of these habitats than poor ecosystem health (EPA 2003). These results suggest that a refinement of the lowland macroinvertebrate model (Murray and Western Plains) is needed to develop a more accurate picture of the environmental condition of the Murray lowland rivers (EPA 2003).

Apart from the hydrology scores and the aquatic life score for the Ovens River in ISC reach 1, the remainder of the ISC sub-index scores are moderate to very good (Table 8).

4.1.1 Listings and significance

Fauna

The water-dependent, instream fauna in the lower Ovens includes macroinvertebrates, mammals, reptiles, amphibians, fish and water birds (see Appendices).

Macroinvertebrate assemblages in the lower Ovens are generally in moderate to good condition. Low flows provided by environmental flows assist to maintain riffles and other shallow habitat, while short-term fluctuations in discharge provided by low flow freshes will move sediment and replenish macroinvertebrate habitat (Brookes et al. 2009). Maintaining macroinvertebrate populations is vital for fish and platypus populations as both groups feed extensively on macroinvertebrates (Brookes et al. 2009; Serena and Williams 2010).

Platypus have been reported in the lower Ovens (NECMA Workshop, Wangaratta, February 2015). Their need for surface water and their diet of freshwater invertebrates (Australian Platypus Conservancy 2015) will be protected by the maintenance of low flows and the provision of low flow freshes from environmental flows.

There is a sustained, ongoing, low-density of platypus in the Ovens below Wangaratta which are likely to be maintained by dispersal from Lake Mulwala. In the King River, the upper reaches above Whitfield have good, productive platypus areas, whereas below Whitfield populations of platypus seem to have been significantly impacted by the millennium drought. In the Buffalo River, there is good habitat, and there are high platypus numbers with high production rates. This reach is a high priority reach for platypus (Melody Serena, Australian Platypus Conservancy, pers. comm., 2015).

Three species of freshwater turtles are recorded from the lower Ovens (NECMA Workshop, Wangaratta, February 2015), with the Murray River turtle (*Emydura macquarii*), being the most often caught instream during a study of habitat preferences of fresh-water turtles in the Murray valley of Victoria and New South Wales (Chessman 1988). Its abundance was significantly positively correlated with water body depth, transparency, persistence during dry conditions and flow speed, again indicating that maintenance of minimum low flows and provision of low flow freshes will benefit the lower Ovens instream fauna.

Eighteen native fish species have been recorded in the lower Ovens (see Table 14), eleven of conservation significance in Victoria or at the national level (Table 9), and five of these - Murray cod (*Maccullochella peelii*), trout cod (*Maccullochella macquariensis*), Macquarie perch (*Macquaria australasica*), silver perch (*Bidyanus bidyanus*), and flat-headed galaxias (*Galaxias rostratus*) - are listed under the EPBC Act 1999.

Table 9: Listed native fish species that have been found in reaches of the lower Ovens# CE = critically endangered, E = endangered, V = vulnerable, PT = potentially threatened, DD = data deficient, FFG = listed under the Flora and Fauna Guarantee Act (source: Cottingham et al. 2001; PC&A and MDFRC 2007; Raymond et al. 2007; Raadik 2012; Koehn et al. 2014).

Common Name	Scientific Name	Reach Number					Cons. Status in Vic	EPBC
		R1	**R2**	**R3**	**R4**	**R5**		
Trout cod	*Maccullochella macquariensis*	✓		✓	✓	✓	CE, FFG	E
Murray cod	*Maccullochella peelii*	✓		✓	✓	✓	V, FFG	V
Macquarie perch	*Macquaria australasica*	✓	✓		✓	✓	E, FFG	E
Silver perch	*Bidyanus bidyanus*					✓	E	V
Golden perch	*Macquaria ambigua*	✓		✓	✓	✓	V	-
Freshwater catfish	*Tandanus tandanus*					✓	E	-
Mountain galaxias	*Galaxias olidus*	✓	✓	✓	✓	✓	DD	
Flat-headed galaxias	*Galaxias rostratus*					✓	V	V
Murray-Darling rainbowfish	*Melanotaenia fluviatilis*					✓	V, FFG	-
Southern pigmy perch	*Nannoperca australis*				**?**	✓	V	-
Unspecked hardyhead	*Craterocephalus stercusmuscarum fulvus*					✓	FFG	-

#Includes stocked and translocated fish

Flora

There are 20 listed species, all of which are regarded as significant under the Victorian FFG Act and 2 species are listed under the EPBC Act at the national level (Table 10). Water management within the system will be an important factor in supporting these species.

Table 10: Listed water-dependent plant species of the Ovens and King Rivers (source: Victorian Biodiversity Atlas search, March 2015). **EPBC Status**: Vu = Vulnerable. FFG status: L = listed; **Vic Status** = status on Advisory List of Threatened Fauna (DEPI 2014): Vu = Vulnerable; R = Rare; Pk = Poorly known; En = Endangered.

Common name	Scientific name	EPBC Status	FFG status	Vic status
Slender Club-sedge	*Isolepis congrua*		L	Vu
Swamp Leek-orchid	*Prasophyllum hygrophilum*		L	En
Warby Range Swamp-gum	*Eucalyptus cadens*	Vu	L	Vu
Rough Eyebright	*Euphrasia scabra*		L	En
Alpine Triggerplant	*Stylidium montanum*		L	R
Common Pipewort	*Eriocaulon scariosum*		L	R
Button Rush	*Lipocarpha microcephala*		L	Vu
Tufted Club-sedge	*Isolepis wakefieldiana*		L	R
Single Bladderwort	*Utricularia uniflora*		L	Pk
Tall Club-sedge	*Bolboschoenus fluviatilis*		L	Pk
Green-top Sedge	*Carex chlorantha*		L	Pk
Hornwort	*Ceratophyllum demersum*		L	Pk
Dwarf Brooklime	*Gratiola pumilo*		L	R
Water Shield	*Brasenia schreberi*		L	Vu
Common Fringe-sedge	*Fimbristylis dichotoma*		L	Vu
Pale Spike-sedge	*Eleocharis pallens*		L	Pk
Slender Bitter-cress	*Cardamine tenuifolia*		L	
River Swamp Wallaby-grass	*Amphibromus fluitans*	Vu	L	
Summer Fringe-sedge	*Fimbristylis aestivalis*		L	Pk

4.1.2 Ecosystem Functions

The lower Ovens provides a range of ecosystem functions, including connectivity across its floodplain and associated wetlands, contributing to primary production and migration/dispersal of biota, and the transportation and dilution of nutrients and organic matter from the floodplain. Of particular relevance to the instream component of the ecosystem is: the maintenance of habitats and populations; provision of habitat diversity; connectivity with the Murray River and therefore with other tributaries of the Murray; and provision of unregulated flows to important sites downstream of the Murray River. These are elaborated on in Table 11.

Instream habitat has two components – structural and hydraulic. Structural habitat is the instream benches, deep holes, undercut banks, woody debris, aquatic vegetation and overhanging vegetation of a river. Hydraulic aspects of habitat are provided by flowing waters which interact with the structural aspects. Having a diversity of both types of habitat is important to large bodied fish and a suite of macroinvertebrates in the Murray River system. Habitat diversity is an important determinant of invertebrate and aquatic fauna abundance and community composition in aquatic ecosystems (van de Meutter et al., 2005; Brookes et al. 2009). Flows contribute to habitat diversity and food resources and the structural aspects of habitat provide protection from predators as well as food resources for macroinvertebrates and fish (Walker 1986, van de Meutter et al., 2005; Brookes et al. 2009; Kingsford et al. 2014).

Instream flows inundate benches and engage low lying areas within the river channel. This creates slackwater habitats which act as refuges from currents for larvae and young fish, while providing abundant food resources (Humphries et al. 2006). Zooplankton and microinvertebrates are hypothesised to provide a critical food source for juveniles of large-bodied fish (Lloyd et al. 1991; Boulton and Lloyd 1992; Geddes and Puckridge 1989; Brookes et al. 2009; Kingsford et al. 2014; Kobayashi et al. 2015). The benches and potential slackwater habitats adjacent to flow water in the Ovens are of high value as they support Murray cod and trout cod recruitment because of these processes.

During very low flows the riverine pools dry and become isolated. This isolation and concentration of biota into pools and declining water quality (increasing salinity and reducing dissolved oxygen) may result in higher mortalities from physiological stress, increased predation, and competition (Walker 1986, Lloyd et al. 1994).

These phases of inundation and drying of riverine and riparian margins result in significant carbon and nutrient fluxes which drive ecosystem processes in these systems (Burns, Robertson & Hillman 2001; Kingsford et al. 2014). Nutrient pulses occurred a few days after floodplain sediments which were experimentally inundated (Briggs et al. 1983; Boulton and Lloyd 1992), which demonstrates the important stimulus role of inundation. Concentrations of organic carbon were positively correlated to leaf-fall from river red gum, phytoplankton productivity, and biomass of aquatic plants (Burns, Robertson & Hillman 2001; Kingsford et al. 2014; Kobayashi et al. 2015).

Table 11: Key instream ecosystem functions of the lower Ovens system. Information is sourced as described or from Lloyd et al. 1994; Humphries and Lake 2000; Cottingham et al. 2001; Treadwell and Hardwick 2003, King et al. 2003, King 2004a; PC&A and MDFRC 2007; Cottingham et al. 2008; Brookes et al. 2009; King et al. 2009; King et al. 2010; Kingsford et al. 2014; Koehn et al. 2014).

Ecosystem Function	Description*
Maintenance of fish habitats	Murray cod and other fish species have been found to be widespread throughout the river system, utilising the abundant large woody debris, anabranches and pools as habitat. Lowland riparian habitat is also an important refuge for threatened native fish species such as Trout cod and Murray cod (Koehn et al. 2014).
Maintenance of populations	Threatened species (flora and fauna), include up to eleven native fish species of State and national conservation significance and icon species such as Murray cod.
Provision of habitat diversity	Habitat diversity includes instream features such as abundant large woody debris, cobbles, riffles, pools, bars, anabranches, flood runners and the littoral fringe.

Ecosystem Function	Description*
Connectivity	Fish movement across the river system throughout the year, as well as movement into anabranches is important. Connectivity between the upper reaches of the Ovens River system, and the Murray River and Lake Mulwala downstream, are also important. Murray cod and other native species have larvae that drift downstream. It is therefore important to view the river system as a continuous system for flow management (Broadhurst et al. 2013).
Provision of unregulated flows	The Ovens River is one of the few remaining rivers in Victoria where flooding can occur in a relatively natural setting and is widely recognised as the least regulated of the major Murray Darling tributaries. These contribute to the Ovens being important for water yield, water quality, floodplain connection and fish migration.

4.2 Social Values

The consideration of social values is limited to the instream and riparian zones within and immediately adjacent to the stream channel because of the scope of environmental water management within the lower Ovens. Community involvement is important in river rehabilitation projects (whether this is flow or habitat based) as these need to be supported by community involvement. River rehabilitation may include return of flows components to a system, re-snagging and revegetation, science investigations and community education (Frawley et al. 2011).

4.2.1 Cultural heritage

Indigenous cultural heritage

There is little information recorded in previous reports or publications describing indigenous values of the lower Ovens system and the few values recorded are more focused on the catchment (e.g. scarred trees and artefacts as well as spiritual and historical ties with the land) rather than instream values.

Traditional Landowners value and use water in multiple and integrated ways for resources such as food, medicines and crafts as well as recreation and cultural practices (Jackson et al. 2015). Fish are regarded as important to traditional owners and Murray cod are principal amongst fish (Gondwana Consulting undated).

Consultation with indigenous groups is essential to ensure the EWMP is widely accepted and importantly, environmental flow management of the system could be improved if indigenous knowledge is included. Jackson et al. (2012 & 2015) provide principles and guidelines for best practice engagement with indigenous groups in water planning. Jackson et al. (2014) provide a framework for incorporating indigenous knowledge into flow studies. It is recommended these programs are incorporated into the implementation phase of this EWMP as while some indigenous consultation was attempted in the preparation of this EWMP it was not comprehensive.

General cultural heritage

The importance of the social and cultural contributions from the river system is reflected in the strong community involvement in the management of its waterways.

The lower Ovens also offers an educational resource for primary through to tertiary students, as well as community education. This includes demonstration reaches such as those for the MDBA fish recovery project, as well as education for the whole community of indigenous history and values through projects such as new Bullawah Cultural Trail Project.

4.2.2 Recreation

The lower Ovens catchment is currently a popular recreational destination, for people local to the area and also from outside of the region. As well as bushwalking, camping, hunting, four-wheel driving and regional festivals, there are many water-based recreational pursuits within the system, including:

- fishing;
- boating;
- kayaking;
- swimming;
- camping;
- walking/passive recreation;
- water skiing; and
- rafting.

4.3 Economic Values

The water itself within the Ovens River is an important economic resource contributing reliability and variability to the flow regime for a range of important downstream uses, including irrigation, urban supply, and environmental water for downstream sites/reaches, and delivering substantial volumes to the Murray River.

The recreational tourism activities described above are also important economic contributors to the region.

4.4 Conceptualisation of the Site

The ecological processes and their interaction are displayed in Figures 4 to 6.

The three key elements of the aquatic environment for river fauna (see Figure 4) – the physical habitat, water quality and the biological habitat – are all strongly influenced by flow regime. Each of these elements contributes to the composition and function of the fish and macroinvertebrate faunas, which are key measures of river health in Victoria.

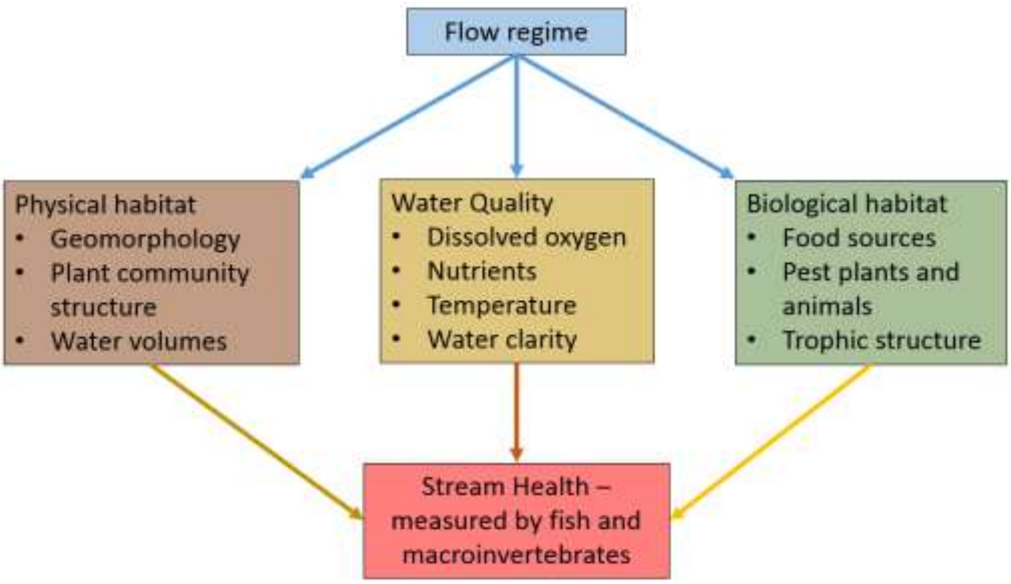


Figure 4: Flow regime and environmental values in the Ovens River.

Through the transport and deposition of sediment of all sizes, stream flow alters the form (geomorphology) of the river's bed and banks. This is important for the provision of deep holes and migratory paths for the fish community, as well as substrate diversity and habitat heterogeneity for the fish and macroinvertebrate communities.

Flow rates and timing (frequency and seasonality) also influence the physical habitat structure created by the plant community by providing conditions that favour some species over others and also controlling the distribution of plants. Plant community structure provides resting habitat and refuge for macroinvertebrates and fish. The volume of water in a reach also influences the amount and variety of habitats available. More water within a reach results in more habitat volume, but when accompanied by increased flow velocities can alter the habitat suitability for each species.

Water quality is also affected by the flow regime through the transport of nutrients, the physical mixing of water, the change in ratio of groundwater to surface water inputs, and the support for biological processes such as photosynthesis and decomposition of organic matter. These processes contribute to the concentrations of nutrients, salts and dissolved oxygen, as well as water temperature and clarity.

Flow regime also affects the biological habitat by the provision of conditions more suitable for different taxonomic and structural plant groups (e.g. macrophyte versus algal dominated), which flows through the types of food sources available and the trophic structure of the river. Flow regime is also important in terms of its suitability for native plant and animal species rather than favouring pest species.

Another important process is connectivity within the system and between the Ovens and the Murray. Flow freshes allow a physical connection between the reaches of the system and between the two river systems but allowing fish to move across riffles and bars in the system. Very low flows can isolate sections of the system and prevent fish migrating along the system to feed, find habitat or mates and to spawn. Therefore flow freshes will have an important contribution to ecosystem health and biodiversity in both the Ovens and the Murray Rivers.

The threats posed by an inappropriate or inadequate flow regime cannot be considered in isolation from the stresses placed on the lower Ovens River by human changes to the river catchment and channel (Figure 5). Some of the major changes to the catchment and channel that need to be considered in relation to flows include:

- Stock grazing in the catchment (changes to hydrological rates and sediment delivery to the channel) and stock access to the river (increasing bed slumping/riparian erosion and direct water contamination and disrupting macrophytes communities and riparian vegetation);
- Historical river management activities designed to reduce flooding, which increase drainage rates and consequently increase erosion, stream sedimentation, channel form and bed/bank stability;
- Construction of levees which change the flooding regime of the river, altering the delivery of sediment, organic matter and nutrients from the floodplain;
- Land use changes in and near the stream channel, including urban and industrial impacts to the riparian zone near town centres, and historical gravel extraction from the channel; and
- The spread of weeds such as willows in the riparian zone of the river, changing channel form, habitat and stability.

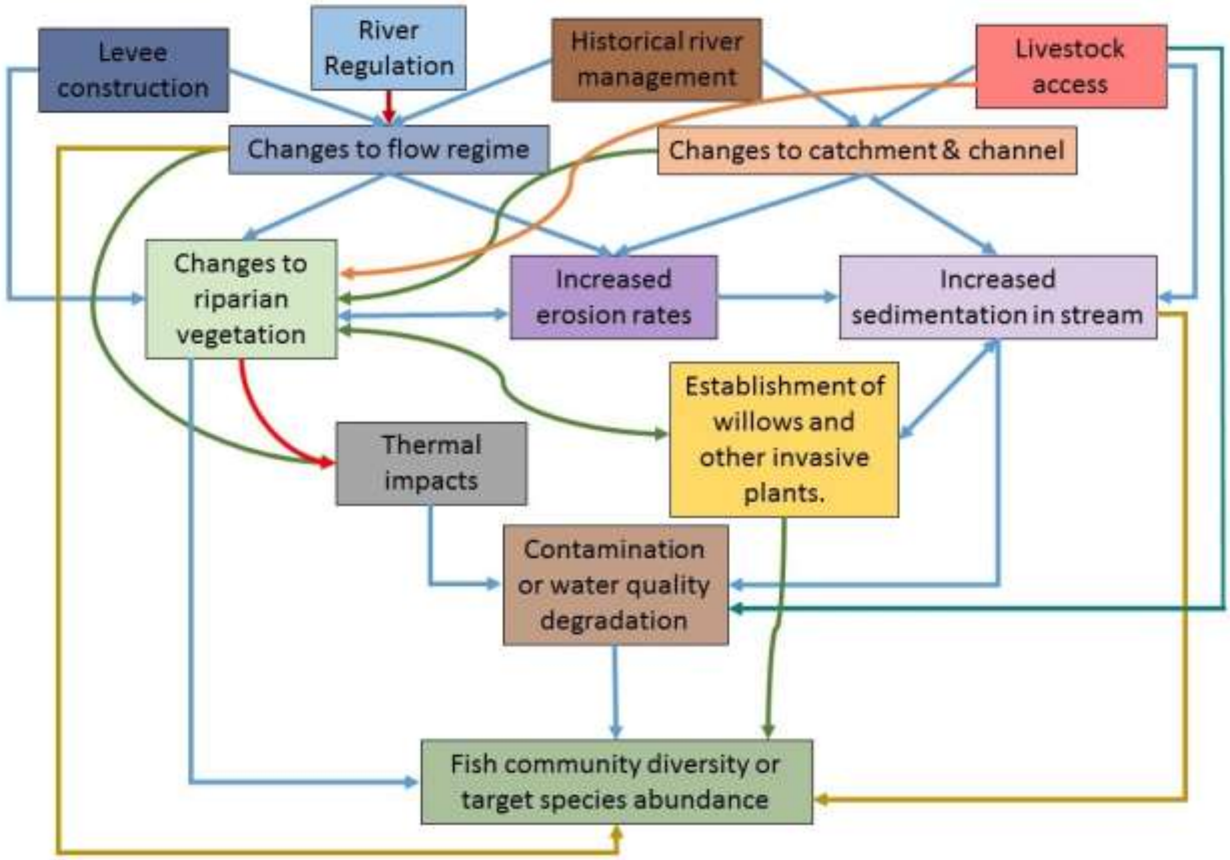


Figure 5: Linkages between threats and the key value of iconic native fish in the lower Ovens River (the multi-coloured lines in this diagram are designed to aid interpretation of the relationships indicated).

The ecology-flow relationships are presented in a flow-based conceptual model (Figure 6) which links the in-channel flow components recommended in the 2008 FLOWS study to flow components, flow and ecological objectives, and the ecological outcome and key values. Summer low flows and flow freshes are the most important flow components for the in-channel processes. Only in-stream components have been shown here as these are the flow components which can be influenced by the management of regulated flows within the Ovens System. Other flow components do occur and are critically important to the ecosystem function and conservation status of the system (Cottingham et al. 2008) but these flow events occur naturally or are out of the control of releases from storages, so are not considered further here.

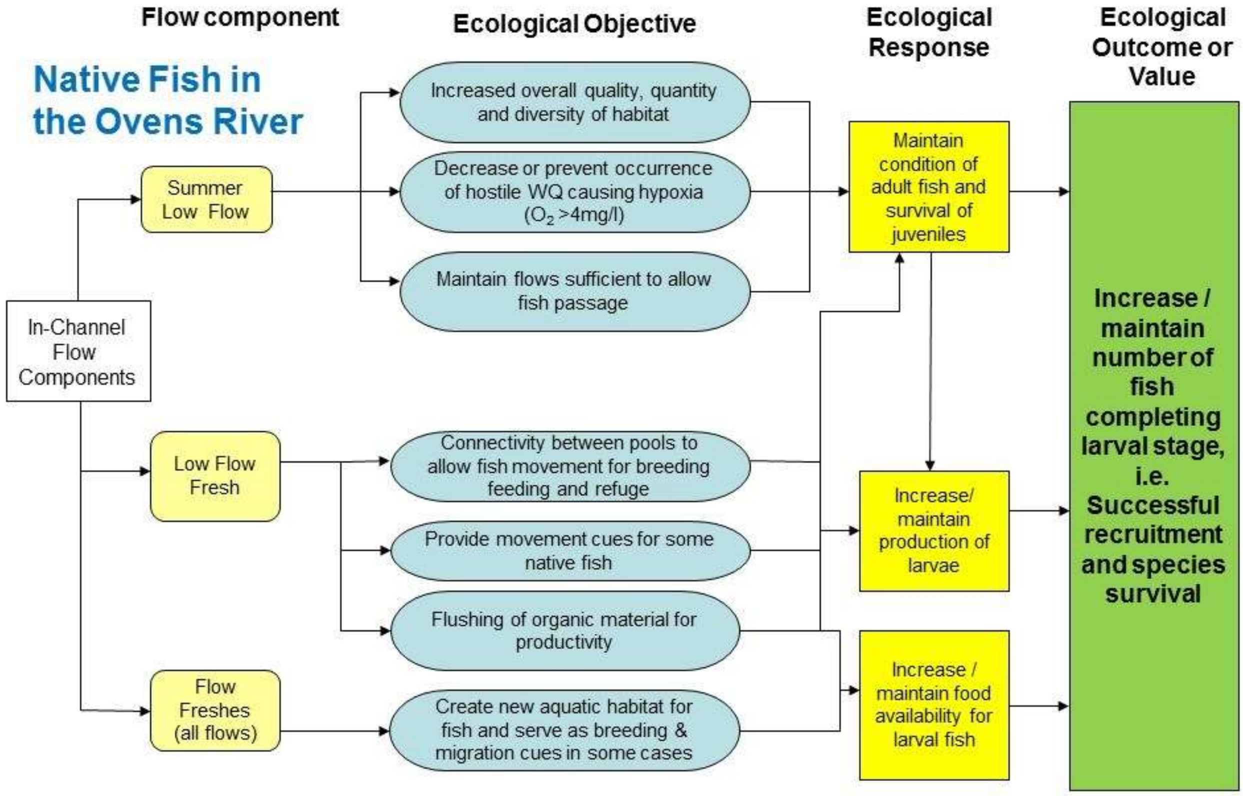


Figure 6: Ecology-flow relationships for native fish in the lower Ovens River.

These processes drive some of the important ecological functions leading to the recruitment of the key species of Trout Cod, Macquarie Perch and Murray Cod within the lower Ovens River.

Low flows provide summer refuge for adult and juvenile fish (Koehn et al. 2014). This can consist of flowing water or pooled main channel habitats. Low flows may keep part of the channel full of water or, at least, provide pools within channels with some flow to counter evaporation (Bond and Lake 2003a and b, Pusey et al. 2000). These flows also moderate temperatures over the summer period (Sabo et al. 1999) which also supports fish as cooler water has more dissolved oxygen. Pools can also provide habitat for macroinvertebrates which require permanent water (Boulton and Lloyd 1991) and these support the food chain (Arthington and Pusey 2003; King 2004b). Periods of low flow can, however, provide greater areas of still water habitats, which result in greater densities of microinvertebrates because of the longer residence time of water (King 2004b). Further, there is some evidence for low flow recruitment and growth of larvae in the Murray-Darling River systems (Humphries et al. 1999).

Deeper holes within the river channel provide refuges and shelter in drought years and hot summers for Murray cod, golden perch and other large bodied fish (Mallen-Cooper and Stuart 2003, Treadwell and Hardwick 2003; Jones and Stuart 2007; Koehn et al. 2014).

Low oxygen conditions are not only physiologically stressful for fish, they can lead to exotic fish, such as eastern gambusia and carp, dominating if these conditions persist (Lloyd 2012; King et al. 2012a, Beesley et al. 2014). These exotic fish have the ability to survive in near anoxic conditions (Lloyd 2012; King et al. 2012a) compared to native fish (McNeil & Closs 2007). Blackwater events (often resulting from flow releases after long periods of very low flow) can lead to hypoxia and death of fish and invertebrates (King et al. 2012a; Ning et al. 2015). The events in late 2010 in the Murray led to reduced abundances of invertebrates and native fish (but exotic fish fared better). Flowing water prevents build-up of blackwater and oxygenates the water. Flow releases should be avoided in late summer when high temperatures and leaf litter has built up (King et al. 2012a; Ning et al. 2015).

Low flow freshes are required in rivers to stimulate nutrient release (critical in ecosystem productivity) and movement along rivers in spring and early summer (Humphries and Lake 2000, Treadwell and Hardwick 2003, King et al. 2003, King 2004a; King et al. 2009). These events need to occur annually for smaller species and every 3-5 years for larger species. Even fish which do not require flooding as a breeding trigger can exploit the productivity boost resulting from such freshes for growth or larval survival (Humphries and Lake 2000, Treadwell and Hardwick 2003, King et al. 2003, King 2004a; King et al. 2009; Kingsford et al. 2014). These events can also serve as a precursor to larger flooding events (which are likely to be useful in breeding events) and the increased productivity can allow adult fish to gain condition in anticipation of breeding.

Instream flows inundate benches and engage low lying areas within the river channel which provides abundant food resources (such as zooplankton and microinvertebrates) for both small-bodied fish and the juveniles of large-bodied fish (Lloyd et al. 1991; Boulton and Lloyd 1992; Geddes and Puckridge 1989; Humphries et al. 2006; Brookes et al. 2009; Kobayashi et al. 2015).

Larger freshes (and flooding events) which inundate vegetation beds, dry anabranches and in-channel benches, create significant areas of new habitat and allow macroinvertebrate populations to grow rapidly (Hillman and Quinn 2002, Jenkins and Boulton 2003, King 2004b). Invertebrates lay eggs and resting stages in floodplain and wetland sediments which hatch following inundation, leading to a rapid increase in population (Boulton and Lloyd 1992, Jenkins and Boulton 2003). These build very large biomasses of microinvertebrates and macroinvertebrates following inundation that provide adult fish with adequate food to build condition for spawning (Pusey and Arthington 2003, King 2004a, King 2004b. Depending upon the timing, size and nature of the event, they can stimulate breeding and recruitment of many native fish (Lloyd & Walker 1986, Treadwell and Hardwick 2003, Vilizzi et al. 2007; King et al. 2010; Koehn et al. 2014). Furthermore, these events provide opportunities for small bodied native fish to move around between habitats (or to be moved about by the flows).

Given that many of the small bodied fish live only one or two years, these flows are required annually. Larger events do not have to occur every year, but during breeding season for golden perch, silver perch, trout cod and Murray cod (Bond and Lake 2003b, Treadwell and Hardwick 2003). Fish, such as Murray cod, may not require high spring flow pulses to trigger spawning (per se), but the survival of their larvae or juveniles does depend on productivity derived from these events, so these flow events are critical to these species survival also (Kingsford et al. 2014).

In summary, the following flows are instrumental in ensuring the following processes:

Summer low flows

- Increasing overall quality, quantity and diversity of habitat
- Decreasing or prevent occurrence of hostile WQ causing hypoxia (O_2 >4mg/l)
- Maintaining flows sufficient to allow fish passage

Low flow freshes

- Connectivity between pools to allow fish movement for breeding, feeding and refuge
- Providing movement cues for some native fish
- Flushing of organic material for productivity

Flow freshes at all flows and times of the year

- Providing flow pulses that can also create new aquatic habitat for fish as well as serving as breeding and migration cues in some cases.

4.5 Significance

The lower Ovens system is a highly significant tributary within the Murray-Darling system for a range of reasons, including:

- It has been designated a Heritage River (the lower reaches, from Killawarra to Lake Mulwala) and is one of the largest, mostly unregulated waterways in the Murray-Darling Basin;
- The entire lower Ovens system is of high environmental value due to its relative intactness and near natural flow regime;
- It supports of a variety of threatened and endangered flora and fauna species including up to ten native fish species of State and national conservation significance and icon species such as Murray cod;
- Connectivity within the Ovens system and into the Murray River enables fish movement across the system and downstream drift of fish larvae throughout the year; and
- The lower Ovens River is a genuine community asset, providing environmental, economic, social and cultural benefits to the region.

5 ECOLOGICAL CONDITION AND THREATS

5.1 Current condition

Context

The Ovens River's current flow regime is typically experiencing flows with winter high flows occurring between summer/autumn low flows (Figure 7).These 'typical' flows are occurring after an extended low-flow period that was followed by a relatively wet period (Figure 7).

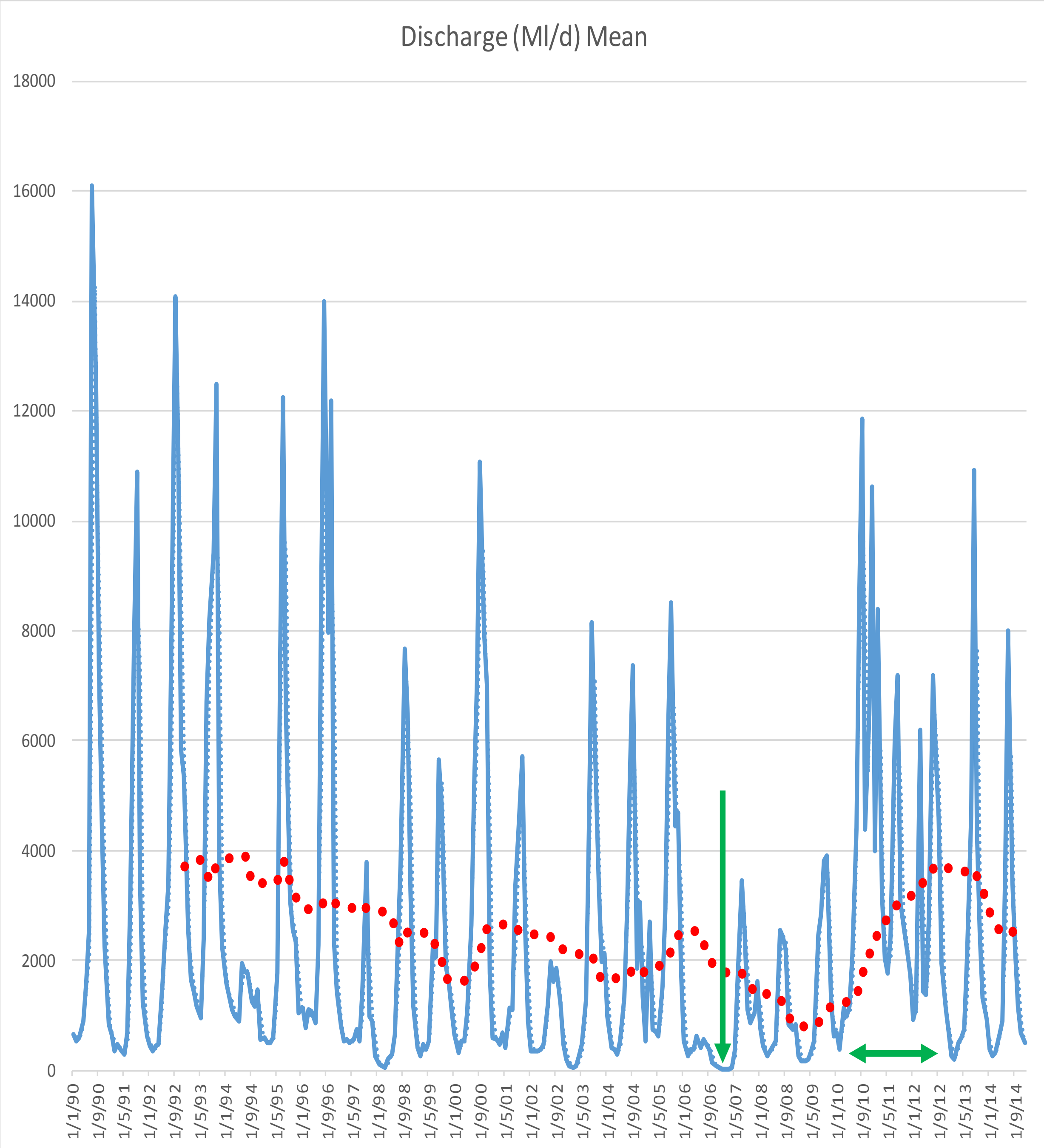


Figure 7: Mean monthly discharge in the Ovens River at Wangaratta (Jan 1990 to Sep 2014)[4]. Vertical green arrow shows cease-to-flow period in 2006; horizontal green arrow shows unusually wet period 2010 to 2012. Red dotted line shows moving average of previous 36 months.

[4] Source: http://data.water.vic.gov.au/monitoring.htm

During the extended low flow period between 2006 and 2010 (part of the 'Millennium Drought'), flows were the lowest on record with extended cease-to-flow periods raising concerns about the short and long term effects of extreme low flow events. The relatively wet period between 2010 and 2012 included several significant flood events.

Conditions during 2012-13 and 2013-14 were drier and warmer than average during summer and autumn months (SKM 2007; NECMA 2014a; BOM 2015). For environmental water planning and delivery purposes in the Ovens River System, it is the volumes during the summer to autumn months of regulated flows that are important. The data indicates that the December to March inflows into the storages for the past three years have been substantially below average (Table 12).

In this situation, the provision of environmental minimum flows and, where appropriate, low flow freshes, will contribute substantially to the maintenance of habitats and habitat diversity.

Table 12a: Inflow and release data for Lake Buffalo (Source: Data supplied by GMW)

Lake Buffalo Inflows												
Water Year	**Jul.**	**Aug.**	**Sep.**	**Oct.**	**Nov.**	**Dec.**	**Jan.**	**Feb.**	**Mar.**	**Apr.**	**May**	**Jun.**
2012 - 13	109,215	74,609	53,801	19,237	9,838	6,728	2,181	1,658	6,340	3,907	7,800	21,421
2013 - 14	75,493	171,418	49,587	28,628	11,397	9,874	3,851	465	1,938	4,032	11,614	45,692
2014 - 15	103,801	41,330	20,861	10,184	5,017	3,009	1,702	1,166	145	2,900		
Average	72,279	70,233	62,496	62,499	30,702	17,738	9,567	4,918	5,032	9,301	15,463	35,891
Lake Buffalo Releases												
Water Year	**Jul.**	**Aug.**	**Sep.**	**Oct.**	**Nov.**	**Dec.**	**Jan.**	**Feb.**	**Mar.**	**Apr.**	**May**	**Jun.**
2012 - 13	109,486	74,482	54,604	11,458	8,055	6,561	2,639	4,475	7,661	8,838	9,727	20,173
2013 - 14	76,312	171,643	49,039	20,616	10,065	8,382	3,727	4,579	4,915	6,297	11,875	45,424
2014 - 15	106,213	37,564	21,209	6,201	5,225	3,708	2,898	4,245	6,793	5,587		
Average	66,063	85,067	74,319	53,635	26,906	16,399	8,455	8,853	9,891	9,460	15,482	27,991

Table 12b: Inflow and release data for Lake William Hovell (Source: Data supplied by GMW)

Lake William Hovell Inflows												
Water Year	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.
2012 - 13	53,679	35,597	28,935	10,110	5,524	3,860	1,487	1,222	2,723	2,408	4,704	13,241
2013 - 14	36,808	73,697	23,903	14,937	6,668	5,788	2,078	938	1,173	2,002	6,904	29,653
2014 - 15	55,551	21,998	10,263	5,796	2,976	2,179	1,561	917	703	1,600		
Average	34,754	33,293	29,952	27,150	13,087	7,959	4,768	2,593	2,525	4,383	7,923	17,742

Lake Williams Hovell Releases												
Water Year	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.
2012 - 13	53,807	35,679	29,148	10,258	5,223	3,963	3,472	2,972	2,231	1,794	1,853	13,459
2013 - 14	36,787	72,444	23,850	15,292	6,714	6,656	3,555	3,365	3,223	2,936	1,971	30,666
2014 - 15	53,666	21,753	11,000	6,219	3,053	2,821	2,572	2,843	3,265	2,369		
Average	30,363	38,700	35,852	25,620	13,829	9,313	5,482	5,001	5,229	4,898	6,529	12,149

Sustainable Rivers Audit (SRA)

Undertaken at the basin scale, the SRA (Davies *et al*. 2008; 2012) provides the most comprehensive assessment of river health undertaken for the Murray-Darling Basin. The SRA provides assessments of the Basin's river valleys, based on assessment of fish, macroinvertebrates, vegetation, physical form and hydrology. These are then compared to reference condition to derive an audit score (where 'reference condition' is an estimate of condition prior to European settlement).

Two audits have been undertaken: SRA1 and SRA2. SRA 1 is based on data collected from 2004 – 2007 and assessed fish, macroinvertebrates and hydrology. SRA 2 is based on data collected from 2008 to 2010 and includes additional reports on physical form and vegetation. Issues complicating a comparison of the two assessments include the fact that some data for the first assessment were gathered during the beginning of the Millennium Drought and much of the data gathered for the second audit was collected during the most severe conditions of the Millennium Drought. Also, changes in methodology and additional information collated need to be considered.

The SRA1 report assessed the Ovens Valley river ecosystem as being in poor health: (Lowland and Slopes Zones: Poor; Upland Zone: Very Poor; Montane Zone: Moderate. The majority of the lower Ovens (as defined for this EWMP report) is in the Lowland Zone of the SRA, some is in the Slopes Zone, a small part is in the Uplands Zone and none is in the Montane Zone.

Fish abundance was dominated by native species, but biomass was dominated by aliens and several expected species were absent. No Macquarie perch, mountain galaxias or obscure galaxias, and only a single southern pygmy perch, were caught in Zones where they were predicted to be common. Other species not caught, but predicted to occur rarely or occasionally under Reference Condition included bony herring, freshwater catfish, silver perch, golden perch and trout cod, as well as several small, less well-known species (Davies *et al*. 2008). Many expected and several disturbance-sensitive macroinvertebrate families were also absent.

The flow regime showed little change from Reference Condition, other than changes to low flows in the Lowland Zone (where sites on the Ovens and King Rivers showed a large difference from Reference Condition, mainly because in December to June the volume of the minimum monthly flow and the lowest 10^{th} percentile monthly flow were reduced compared to modelled natural conditions (Davies et al. 2008). This was at the beginning of the Millennium Drought, so it is likely to have affected flow conditions. Flows would have been at record lows during the second audit as this was undertaken taken in the most severe conditions of the Millennium Drought. The SRA2 report (Davies et al. 2012) also rated the Ovens Valley as being in Poor Condition, with little change in the description from SRA1, although the assessment of physical form in SRA 2 was rated as being in Good Condition.

Index of Stream Condition (ISC)

The ISC provides a snapshot of river health across the State. The results of the third (2010) ISC relevant to the lower Ovens were presented in Section 4 (Table 8) of this report. A comparison of results from the first (1999), second (2004) ISC and third (2010) reports is presented in Table 13. It should be noted that ISC river reaches are numbered and selected differently from those in the 2008 Environmental Flow Study that the reaches in this proposal correspond to. The table below uses ISC data that covers the five river reaches in this proposal.

Table 13: Index of Stream Condition scores for the lower Ovens River, 1999, 2004 and 2010[5].

Lower Ovens Reach	ISC Reach	ISC sub-indices															ISC score			Condition rating (1999, 2004 & 2010)
		Hydrology			Physical form			Streamside zone			Water quality			Aquatic life						
		1999	2004	2010	1999	2004	2010	1999	2004	2010	1999	2004	2010	1999	2004	2010	1999	2004	2010	
1	33	6	6	4	6	3	6	7	5	7	-	-	-	8	6	6	32	23	24	Moderate
2	22	10	4	4	6	7	7	7	6	7	9	7		8	5	8	37	26	28	G*, M*, M
	23	10	4	4	6	6	7	6	5	7	-	-	-	-	4	7	33	22	27	Moderate
	24	10	4	4	8	6	7	8	3	8	10	-	8	9	8	6	43	22	30	E*, M, M
3	21	10	3	4	7	6	9	5	5	7	-	-	7	9	5+		35	22	31	G, M, M
4	4	4	4	5	6	4	7	5	5	7	10	-	8	-	8	7	27	23	32	Moderate
5	1	4	4	5	9	7	7	7	6	8	8	6	9	6	5	4	30	26	29	Moderate
	2	4	4	5	6	7	7	8	8	9	-	-	-	6	5	7	27	27	31	Moderate
	3	4	4	5	6	7	9	4	6	7	-	-	-	9	4	-	25	24	32	P*, M, M

.

* E = Excellent, G = Good; M = Moderate; P = Poor.

[5] Data source: http://ics.water.vic.gov.au/ics/

All 270km of the Ovens, Buffalo and King rivers covered in this EWMP were rated as in moderate condition for the two most recent assessments. This relative stability in condition is encouraging considering that the data for the 2010 assessment was collected over a six-year period that coincided with the severe Millennium Drought (from 1997-2009) as well as major bushfires across the Ovens and King catchments. These events resulted in periods of very poor water quality and loss of habitat, particularly along the reaches of the Ovens River (NECMA 2014a). Interestingly, the first (1999) ISC score rated one stream reach as Excellent (King River, immediately downstream of Lake William Hovell), two reaches as Good (the two ISC reaches of the King River upstream of its confluence with the Ovens River) and one reach as Poor (Ovens River immediately downstream of its confluence with the King River. The Poor rating was mostly due to Physical Form and Streamside Zone rating lower in 1999 than in the subsequent two assessments.

Fish Populations and Assemblages in the Lower Ovens

The fish fauna of the lower Ovens system is an important component of Victoria’s biodiversity and an integral component of river and floodplain foodwebs and as such have been the focus of considerable scientific research (PC&A and MDFRC 2007). A total of 26 freshwater fish species have been recorded from the 5 study reaches, comprising 18 native and 8 introduced species (Tables 14). Eleven of the native fish species have conservation significance as State and/or national level (Table 9). Reach 5 contains almost all of the native and introduced species recorded within the lower Ovens system (Table 14), indicating it provides good habitat requirements for fish in general.

The Ovens River is considered to support one of Victoria’s best Murray cod populations and upstream of Wangaratta was selected as a site for a demonstration reach under the MDBC Native Fish Strategy (Raymond et al. 2007; DEPI 2014). The improvements that have been achieved to fish habitat (re-snagging, willow removal, fencing), fish biodiversity (carp removed and Macquarie perch stocked) and connectivity (fishway at Wangaratta) has had a significant effect of the fish fauna with more than 4 times increase in Murray cod and nearly 3 times increase in trout cod (DEPI 2014). The provision of environmental flows to the lower Ovens would enhance the recovery and resilience of the fish fauna. The demonstration reach above Wangaratta has been vital in connecting the two lower Ovens reaches and enhancing the area of preferred habitat for at two of the iconic fish species of the system. Connectivity is critically important to Macquarie Perch breeding as they are an obligate river spawners and need to be able to access along the system to find the right conditions and suitable habitats (Broadhurst et al. 2013).

The lower Ovens contains a large amount of structural woody habitat (PC&A and MDFRC 2007) that provides protection from high water velocities and predators, areas in which to seek prey, major sources of food and spawning sites for many species.

Table 14: Freshwater fish species that have been found in reaches of the lower Ovens[6] .

Common Name	Scientific Name	Reach Number				
		R1	R2	R3	R4	R5
Trout cod	*Maccullochella macquariensis*	✓		✓	✓	✓
Murray cod	*Maccullochella peelii*	✓		✓	✓	✓
Macquarie perch	*Macquaria australasica*	✓	✓		✓	✓
Silver perch	*Bidyanus bidyanus*					✓
Golden perch	*Macquaria ambigua*	✓		✓	✓	✓
Freshwater catfish	*Tandanus tandanus*					✓
River blackfish	*Gadopsis marmoratus*		✓	✓	✓	✓
Two-spined blackfish	*Gadopsis bispinosus*	✓	✓	✓	✓	
Mountain galaxias	*Galaxias olidus*	✓	✓	✓	✓	✓
Riffle galaxias	*Galaxias arcanus*	✓	✓	✓	✓	✓
Obscure galaxias	*Galaxias oliros*	✓**?**	✓	✓	✓	✓
Flat-headed galaxias	*Galaxias rostratus*					✓
Murray-Darling rainbowfish	*Melanotaenia fluviatilis*					✓
Southern pigmy perch	*Nannoperca australis*				**?**	✓
Australian smelt	*Retropinna semoni*			✓	✓	✓
Western carp gudgeon*	*Hypseleotris klunzingeri*			✓	✓	✓
Flat-headed gudgeon	*Philypnodon grandiceps*			✓	✓	✓
Unspecked hardyhead	*Craterocephalus stercusmuscarum fulvus*					✓
Brown trout+	*Salmo trutta*	✓	✓	✓	✓	✓
Rainbow trout+	*Oncorhynchus mykiss*	✓	✓	✓	✓	✓
Common carp+	*Cyprinus carpio*	✓	✓	✓	✓	✓
Tench+	*Tinca tinca*					✓
Goldfish+	*Carassius auratus*			✓	✓	✓
Redfin perch+	*Perca fluviatilis*			✓	✓	✓
Eastern gambusia+	*Gambusia holbrooki*	✓	✓	✓	✓	✓
Oriental weatherloach+	*Misgurnus anguillicaudatus*					✓

*a species complex; +introduced species

[6] Cottingham et al. 2001; PC&A and MDFRC 2007; Raymond et al. 2007; Raadik 2012; Koehn et al. 2014; VBA 2015

River Connectivity in the Lower Ovens

The provision of fish passage up and down the lower Ovens is essential requirement for all of the native fish species within the system (for both local and long distance movements). The provision of fish ladders means that lower Ovens, Lake Mulwala and the Murray River are a continuous system in terms of native fish management (PC&A and MDFRC 2007). Fish passage in the Ovens River below the dams is generally good except for one barrier Tea Garden weir (Cottingham et al. 2001) in Reach 4 downstream of Whorouly Creek (Near Everton). The fishway at Wangaratta has resulted in great improvements in connectivity in the lower Ovens, and together with the habitat improvement as part of the Ovens Demonstration Reach project, has resulted in increases in the population levels of the large iconic fish species (DEPI 2014). Lakes Buffalo and William Hovell provide substantial barriers, with Lake Buffalo possibly dividing the small Macquarie perch population in this area (PC&A and MDFRC 2007).

Connectivity is also important to platypus as well as they are very vulnerable to predation by foxes if they have to go overland between pools. Summer freshes are beneficial for connectivity and providing good conditions for macroinvertebrate populations, the major food source for platypus (Melody Serena, APC, pers. comm. 2015).

5.2 Condition Trajectory - Do nothing

The management goal focuses on meeting the ecological needs of the key environmental values of the iconic large-bodied fish populations (Macquarie Perch, Trout Cod and Murray Cod). Although it is sensible to use fish as the focus of the objective, it needs to be emphasised that they are being used as a 'catch-all' for the system; an 'umbrella objective' for the many values that need to be protected. The umbrella ecological objective is to manage the Ovens River's iconic fish species of Macquarie Perch, Trout Cod and Murray Cod and ensure its connection to the Murray River through the provision of an appropriate water regime.

This focus recognises several important features and constraints of the environmental water available to the system:

- Management of the large-bodied, iconic, native fish species requires the care and management of the other biotic and environmental attributes and values of the system along the way;
- For water to reach the lower reaches, it must pass through, and therefore contribute to, the connecting reaches;
- With the quantity of environmental water available (the CEWH allocation, environmental minimum flows, and operation releases) in a mostly unregulated system, environmental water is most likely to benefit the ecosystem during stressful summer periods; and,
- There is limited ability to "finesse" flow rates and the release structures are only able to deliver flows to the nearest 20 ML/d.

Contributions to passing flows and low flow freshes will maintain flow cues to stimulate movement of native fish; scour biofilms from beds; maintain the natural variability and connectivity of flows that provide food resources for fish and habitat for macroinvertebrates; and provide water of sufficient depth to allow fish movement between habitats.

If environmental water (made up of the CEWH allocation, environmental minimum flows, and operation releases) is not delivered there is increased possibility of a loss of connectivity as well as productivity for the important native fish, including several listed species. There will also be reduced habitat quality, quantity and heterogeneity.

6 MANAGEMENT OBJECTIVE

6.1 Management Goal

The management goal identifies the vision for the long term health of the target values of the system. The management goal for the Ovens River EWMP is built upon the assumption that the flows required to meet the needs of the iconic large-bodied fish are also those which are required by other components of the ecosystem such as small fish species, macroinvertebrates and aquatic vegetation.

The ecological needs of the large-bodied fish species also cover the ecological needs of other components of the ecosystem because of the interconnections between habitat diversity (principally aquatic & riparian vegetation and structural habitat), invertebrates and fish populations. The important roles of macroinvertebrates, such as yabbies, shrimps and insect larvae, and small fish is in part due to their role in nutrient and organic matter processing and, in part, because of their importance in the diets of large-bodied fish (Walker 1986, van de Meutter et al., 2005; Brookes et al. 2009; Kingsford et al. 2014). Invertebrate populations are also important in the food chains of other fish, frogs, platypus, turtles and waterbirds (Raymond et al. 2007; Brookes et al. 2009; DEPI 2014).

This assumption is supported by the FLOWs studies for the Ovens (Cottingham et al. 2008) and much of the literature (Lloyd et al. 1994; Humphries and Lake 2000; Cottingham et al. 2001; Treadwell and Hardwick 2003, King et al. 2003, King 2004a; PC&A and MDFRC 2007; Brookes et al. 2009; King et al. 2009; King et al. 2010; Kingsford et al. 2014; Koehn et al. 2014). The flow recommendations of the previous FLOWs studies were based on the agreed ecological values of the Ovens River and focussed on the large iconic and threatened fish species present within the Ovens River System.

The long-term environmental water management goal is to:

> ***Use the environmental water reserve, and water management of the Ovens River, to build viable populations of iconic native fish and ensure that they are resilient.***

It aims to use the quantity of Commonwealth environmental water available (70ML) as well as creative (or innovative) delivery of passing flows and consumptive water, to contribute environmental benefit. Further, water is available via management of flows released from drawdowns to transfer to the Murray System, which can be used in the wetter years, but not in all years.

The long term management goal for the Ovens River was developed through the review of literature and information by the project team (see Reference Section), supported by the goals identified in the North East CMA Waterway Strategy goals and stakeholder consultation (Appendix y). The goal is built upon the environmental values documented in Section 4, and aims to manage the issues and threats to ecological condition of the key values identified (Section 5).

In summary, the management goal for the EWMP meets the ecological needs of the key environmental values: the iconic large-bodied fish populations (Macquarie Perch, Trout Cod and Murray Cod). The flows proposed as part of the management goal will also ensure that connectivity is maintained between the Ovens River and the Murray River, allow fish to move between both systems. Furthermore, meeting the flow requirements of these important fish species through water management also addresses the requirements of other species and values within the whole river system.

6.2 Ecological Objectives

Ecological objectives translate the management goal into targets that guide the use of available environmental water.

The ecological objectives for the Environmental Water Management Plan are focused upon the three large-bodied "iconic" fish species (Table 15). It is expected that meeting their needs will also meet the needs of the ecological needs of other fish, aquatic fauna and flora and therefore this is a 'catch-all' ecological objective for the system.

Meeting these objectives will support important ecological functions which lead to the recruitment of the key species of Trout Cod, Macquarie Perch, and Murray Cod within the lower Ovens River. Reflecting the management goal, these objectives overlap with the ecological requirements of other components of the ecosystem such as small fish species, macroinvertebrates and aquatic vegetation (Lloyd et al. 1994; Humphries and Lake 2000; Cottingham et al. 2001; Treadwell and Hardwick 2003, King et al. 2003, King 2004a; PC&A and MDFRC 2007; Cottingham et al. 2008; 1Brookes et al. 2009; King et al. 2009; King et al. 2010; Kingsford et al. 2014; Koehn et al. 2014).

Table 15: Ecological Objectives of the key components of the Ovens River system

Ecological Value	Ecological Objective	Water importance / Justification	Required water regime	Consequence of not receiving required regime	Ecological outcome predicted from e-flow
Large-bodied, adult native fish	Maintain condition of more adult fish of target species	Sufficient flows are required to provide a **diverse habitat** for adult fish to select their preferred hydraulic and temperature conditions to maximise their growth and production of eggs. A diverse habitat maximises the production of macroinvertebrates and smaller fish species which are important food items to maintain body condition of large-bodied fish which allows greater reproductive output.	Summer low flows	Insufficient high quality habitat to maintain or improve numbers of adult fish in required condition	Increasing overall quality, quantity and diversity of habitat for more fish to reach good condition
		Flows are required to reduce possibility of hostile **water quality** conditions that can cause death of adult fish.	Summer low flows	Increased likelihood of hypoxic stress and deaths	Decreasing or preventing deaths of adult fish through poor WQ causing hypoxia (O_2 >4mg/l)
		Fish require local and long distance **passage** along the river system to allow dispersal of juveniles and to find adequate food resources and optimal habitat. These movements optimise the condition of adults.	Summer low flows	Restricted movement of adult fish, restricting their condition	Maintaining flows sufficient to allow fish passage to maintain condition
Juvenile native fish	Maintain survival rates of juveniles of target fish species	A **diverse habitat** provides extensive cover for juveniles to survive and grow to adulthood ensuring a resilient population.	Summer low flows	Insufficient high quality habitat for juveniles to thrive	Increasing overall quality, quantity, and diversity of habitat assists juveniles to thrive

Ecological Value	Ecological Objective	Water importance / Justification	Required water regime	Consequence of not receiving required regime	Ecological outcome predicted from e-flow
		Hostile **water quality** conditions can cause death of juvenile fish and reduce spawning rates/success by adults	Summer low flows	Increased likelihood of hypoxic stress and deaths	Decreasing or preventing deaths of juvenile fish through poor WQ causing hypoxia (O2 >4mg/l)
		Fish require local and long distance **passage** along the river system to allow dispersal of juveniles and to find adequate food resources and optimal habitat. These movements maximise the survival of juveniles.	Summer low flows	Restricted movement of juvenile fish, reducing their likelihood of survival	Maintaining flows sufficient to allow fish passage for improved survival options
		Flushing of organic materials from stream banks and benches into pools is an important process in maintaining **river productivity**. This results in macroinvertebrate and zooplankton production critical for juvenile fish survival.	Low flow freshes	Insufficient food production for sustained / improved growth of juvenile fish	Flushing of organic material increasing stream productivity, supporting fish larval production
Native fish larvae	Increase / maintain production of larvae of target fish species	Flows are required to reduce possibility of hostile **water quality** conditions that can cause adults to lose condition, or result in breeding failures.	Summer low flows	Increased likelihood of breeding failures, impacting production of larvae	Decreasing or preventing breeding failures from poor WQ causing hypoxia (O_2 >4mg/l), improving larval production

Ecological Value	Ecological Objective	Water importance / Justification	Required water regime	Consequence of not receiving required regime	Ecological outcome predicted from e-flow
		Low flow freshes provide local **connectivity** between pools in the river system, allow adults to select the optimal conditions for growth and allows larvae the opportunity to spread between pools, increasing their likelihood of survival.	Low flow freshes	Reduced breeding opportunities resulting in reduced larval production	Increased connectivity improving conditions for larval survival
		Some native fish require a flow fresh to **trigger movement** behaviour resulting in fish spreading upstream in readiness for spawning. This benefits larval survival by enhancing the extent of river they can recruit to.		Reduced spawning resulting in reduced larval production	Increased spawning movement cues for native fish, resulting in more larvae
		Flushing of organic materials from stream banks and benches into pools is an important process in maintaining **river productivity**. This results in macroinvertebrate and zooplankton production critical for larval survival and maintaining adult fish condition for breeding.		Insufficient food production for sustained / improved larval growth	Flushing of organic material, increasing stream productivity, supporting fish larval production
		Flow freshes at any time of the year and at any magnitude produce **new habitat** which extends the area fish larvae can forage across and also seek refuge, which maximises their growth and survival.	Flow freshes at all flows and times of the year	Reduced opportunity for extra habitat that would provide food and refuge, thereby limiting growth and survival opportunities.	Increased habitat providing food and refuge, facilitating growth and survival of larvae.

6.3 Hydrological objectives and ten year water regime

The largely unregulated nature of the Ovens System means that most flow targets cannot be met via managed flows and are dependent on natural flow occurrences. Low flows and low flow freshes are the exception.

There is a need to develop a regime that is opportunistic and to use a principles-based approach using the already allocated water available for use. In addition, accessing other forms of water could be used to assist in meeting the remaining flow objectives.

6.3.1 Hydrological Objectives

The hydrological objectives which arise from the ecological objectives and the species flow recommendations for the Ovens River were determined by the Cottingham et al. (2008) FLOWS study. The recommended flow components were based on the important ecological functions to support the requirements of fish, geomorphology, macroinvertebrates and instream vegetation. The flow components in Table 16 are those within management control by the operators (basically restricted to in-channel flows), and those which support the native fish objectives.

These flow components are:

1. Summer low flows.
2. Low flow freshes.
3. Flow freshes at all flows and times of the year.

These are also the flow components which have been most affected by the upstream regulation and abstraction, which is worst in Reach 5, and are as much as 25% less frequent (Cottingham et al. 2008).

High flow components are still required within the system and are, in fact, critical to maintaining the ecological condition of the system. However these are currently delivered naturally by flow events not affected by the current level of regulation and abstraction (relatively low). The Environmental Water Management Plan is focussing upon the flow components that can be currently manipulated within the context of these high flow events occurring at the frequency, extent and seasonality that is currently experienced.

Summer low flows.

Summer low flows are more affected in the downstream reaches of the Ovens (Cottingham 2008) and management of flows should be aimed at replacing those low flows that are being harvested and retained in the upstream reservoirs. These flows are important in all years, but the largest reduction of summer low flows is in dry years by as much as 25%.

Summer low flows are very important to maintain habitats for large-bodied fish to gain and keep sufficient body condition for survival and breeding. The mechanism by which these flows support native fish include:

- replenishing refuge pools (helping reduce poor water quality and high temperatures);
- improving water quality;
- reducing frequency of, or preventing, algal blooms; and,
- flushing low DO or stagnant water.

These flows will be released at a flow of at least 20ML/d which is the limit of reservoir operation.

Low flow freshes.

Low flow freshes introduce variability into an otherwise stable water regime during periods of high consumptive demand or dry conditions. These flows would be particularly important over the warmer months (December to April) where flow variability is typically at its lowest, but should be found in the system during the whole summer-autumn period.

Low flow freshes are very important to maintain habitats for large-bodied fish to gain and keep high enough body condition for survival and breeding. The mechanism by which these flows support native fish include:

- Flushing of organic materials from stream banks and benches into pools is an important process in maintaining river productivity. This results in macroinvertebrate and zooplankton production critical for larval, and juvenile, fish survival and maintaining adult fish in breeding condition.
- Low flow freshes provide local connectivity between pools in the river system, allow adults to select the optimal conditions for growth and allows larvae the opportunity to spread between pools, increasing their likelihood of survival.
- Some native fish require a flow fresh to trigger movement behaviour resulting in fish spreading upstream in readiness for spawning. This benefits larval survival by enhancing the extent of river to which they can recruit.

Opportunities for release are likely where:

- releases can add to an existing flow event to extend the event, minimise losses, and maximise distances travelled downstream; and,
- stand-alone releases could be "pulsed" down the river to address urgent environmental needs. The CMA should note, and report to stakeholders, the limitations that the realistic expectation is that these may only have a small impact on resulting flows and ecological responses may be muted due to losses downstream in the system and attenuation of the flow levels.

Flow Freshes – all year.

Flow freshes should be aimed at creating additional flow variability and particularly targeted towards triggering important ecological queues and meeting higher level flow recommendations. Larger flow freshes at any time of the year produce new habitat which extends the area fish larvae can forage across and also seek refuge, which maximises their growth and survival. These flow freshes are also important in maintaining connectivity between the Ovens and Murray systems. This is particularly important for the iconic large-bodied fish species within the system as they need to migrate, sometimes large distances, from one system to another for breeding, feeding or habitat selection purposes.

These might be created through the managed bulk water releases.

Table 16: Environmental flow recommendations for the lower Ovens, relevant to the EWMP (adapted from Cottingham et al. 2008 and NECMA 2014a).

Ecological objective	**Management zone**	**Flow components**	**Timing**	**Magnitude***	**Duration (Days)**	**Frequency**	**Condition Tolerances**
Maintain condition of more adult fish of target species	In stream	Summer low flow	Summer/ Autumn (Dec – May)	1. 70 – 680ML/d 2. 60 – 415ML/d 3. 26 – 985ML/d 4. 170 ML/d or natural 5. 130 ML/d or natural	Continuous	Continuous	An absolute minimum of 10ML/d in Reaches 1-4 and 85ML/d in Reach 5
Maintain survival rates of juveniles of target fish species	In stream	Summer low flow	See above				
		Low flow fresh	Summer/ Autumn (Dec – May)	1. ≥170ML/d and ≥430ML/d 2. ≥150ML/d and ≥430ML/d 3. ≥120ML/d 4. ≥430ML/d 5. ≥130ML/d - 260ML/d	1. 3 2. 3 3. 4 4. 3 5. 3	1. 2 freshes of each 2. 2 freshes of each 3. 3 freshes 4. 4 freshes 5. 4 freshes	
Increase / maintain production of larvae of target fish species	In stream	Summer low flow	See above				
		Low flow fresh	See above				
		Flow Freshes (all flows and times of year)	Flow freshes in late Winter, spring and summer are most likely to support production of fish larvae	1. ≥5,000ML/d 2. ≥260ML/d 3. ≥105ML/d 4. ≥18,500ML/d 5. ≥540ML/d and 3,900ML/d	1. 1 2. 1 3. 7 4. 1 5. 7	1. 1 fresh 2. 4 freshes 3. 4 freshes 4. 2 freshes every 3 years 5. 4 freshes and 2 freshes of larger fresh	

6.3.2 Ovens River ten year water regime

A ten year water regime for the Ovens River will be different from most other major Victorian waterways due to its mostly unregulated nature and the small regulated entitlement available to the environment. The flow plan, therefore, cannot be specified as a series of flows planned for each year over a ten year period with any great precision. Nonetheless, studies in the Murray-Darling Basin have shown that flows should be managed over longer timeframes and it is suggested that decadal flow regimes be planned across the Basin (Koehn et al. 2014).

Therefore, a set of principles, which can be used to influence how flows are set, and a step-wise process is provided to develop a rolling plan for a ten year period, to determine what the preferred watering plan should be in any particular year. The principles and process are detailed below, as is an example of a ten year water regime, and how three climate scenarios might alter how flows are applied.

Principles to guide the development of seasonal watering plans are:

- All options should relate to meeting low flow ecological objectives;
- The 70 ML of Commonwealth environmental water is best utilised during low flow periods. As this entitlement is so small, infilling or extending a low flow fresh is the most optimal use of this water;
- Environmental minimum flow rules should be revisited to allow greater discretion to both G-MW and NECMA/VEWH for its release. For example, where spare storage capacity exists, water should be allowed to accumulate (subject to evaporative losses) for later release to contribute towards a low flow fresh;
- Formalise and create protocols around communications between G-MW and NECMA/VEWH for the use of bulk release water. This will embed the past good practice, which has provided several ecological benefits, into the future; and
- Encourage further cooperation between agencies for the delivery of consumptive water to diverters and towns. Scope to vary flows (such as pulsing) should become part of routine operations and captured as communication protocols between key agencies, adding environmental benefits from these regular flows.

These principles will guide the development of a rolling water regime plan when implemented using the adaptive management procedure set out in Figure 8.

There are five steps required to develop a rolling ten year water regime for the Ovens River. The five steps will be reviewed each year and updated based on the previous year(s) experience and the climate outlook for the year ahead. An example of a rolling ten year water regime plan is provided in Table 18. This is only an example and would be used as a basis to review in year one of the implementation of this Environmental Water Management Plan.

The five steps are:

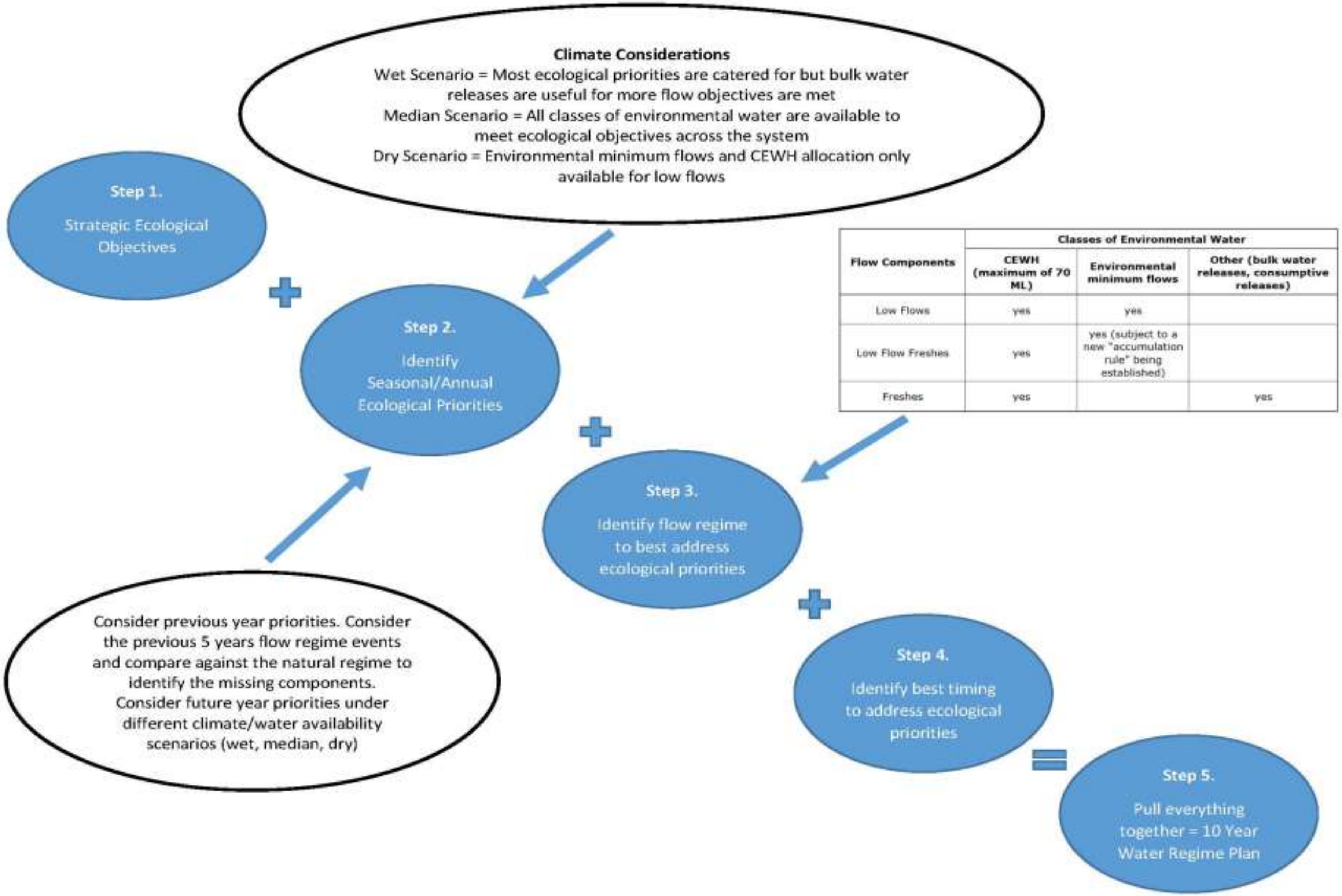
Step 1. Strategic Ecological Objectives

Step 2. Identify Seasonal/Annual Ecological Priorities

Step 3. Identify flow regime to best address ecological priorities

Step 4. Identify best timing to address ecological priorities

Step 5. Pull everything together = 10 Year Water Regime Plan



Flow Components	Classes of Environmental Water		
	CEWH (maximum of 70 ML)	Environmental minimum flows	Other (bulk water releases, consumptive releases)
Low Flows	yes	yes	
Low Flow Freshes	yes	yes (subject to a new "accumulation rule" being established)	
Freshes	yes		yes

Figure 8: Procedure to develop a ten year rolling water regime plan

The lower Ovens, like many river systems, requires adaptive management to attempt optimisation of water resources with incomplete knowledge. A Bayesian network would be a useful tool to assist with decision-making, particularly with testing different water management scenarios. A Bayesian network would address many issues that confront environmental flow management, including: modelling cause-effect relationships; accommodating missing data; flexibility in incorporating new data as it becomes available (including replacing expert knowledge with observational data); scenario testing; preservation of system knowledge; being readily understandable; and useful as a tool in educating people unfamiliar with a system (Hart et al. 2006; Westbury et al. 2006; Westbury et al. 2007; Chan et al. 2012). A useful way to approach the development of a Bayesian network would be to run an expert workshop to develop conditional probability tables for the network. The outcomes from the development process, and the model itself, would contribute substantially to undertaking the five steps described below.

Step 1. Strategic Ecological Objectives

Establishing the strategic ecological objectives is something which is done once and reviewed every five to ten years. These ecological objectives are developed in this document and found in Section 6.2 and specifically in Table 15.

The remaining steps (2-4) are undertaken each year building on the experience gained in the previous year(s).

Step 2. Identify Seasonal/Annual Ecological Priorities

In this step, the seasonal or annual ecological priorities are set by reviewing the current ecological priorities (review section 4, 6.1 and 6.2) in light of the current climate conditions and the understanding of the current or typical hydrology (section 5). The assessment would review any urgent issues, the previous 5 years of flow events, which ecological objectives would be addressed, as well as likely future climate scenarios (review predictions from BoM, but plan using various contingencies). This step should consider how the last 5 years match the flow regime under natural condition. This will identify the missing flow components and also consider how these missing components could be re-instated. This could include an assessment of compliance to the flow recommendations of previous years (using the FLOWS compliance tool) to see if allocated environmental water is sufficient to meet the ecological needs of the system.

Antecedent conditions need to be considered when planning for the following year or subsequent years. One study found that native fish generally responded positively to frequent inundation, while non-native species generally responded positively to long dry periods followed by short-term inundation events (Beesley et al. 2014). Natural flows experienced, and managed flows released, over the past 5 years should be considered when determining various scenarios that may occur in the following year(s). This will lead to the ten-year water regime being a rolling period of ten years rather than a fixed plan, so that the actual allocations will respond to conditions. All plans for the forthcoming year need to have options, so that opportunities can be readily taken to provide additional benefits.

Climate Scenarios	Definition
Wet scenarios	Flows >75 percentile
Average scenarios	Flows ≥25 percentile and ≤75 percentile
Dry scenarios	Flows < 25 percentile

In wet climate scenarios it would be more likely that higher volumes are possible from the Bulk Water Releases to achieve the ecological objectives that require higher flows. In average years the CEWH environmental allocation and environmental minimum flows are most effective. In dry years, the newly proposed accumulation rule for environmental minimum flows would be more effective.

Step 3. Identify flow regime to best address ecological priorities

In this step, the flow components available are examined with respect to the class of environmental water available (Table 17) to build a water regime in the next and future years. Section 6.3.1 and Table 16 provide guidance for this step.

Table 17: Flow regime and classes of environmental water available in the Ovens River System

Flow Components	**Classes of Environmental Water**		
	CEWH (maximum of 70 ML)	**Environmental minimum flows**	**Other (bulk water releases, consumptive releases)**
Low Flows	yes	yes	
Low Flow Freshes	yes	yes (subject to a proposed new "accumulation rule" being established, see page 24 and 57)	
Freshes	yes		yes

Step 4. Identify best timing to address ecological priorities

This step considers when the flow events are delivered to best achieve the ecological objectives set out in Table 15 and 16. This would consider all the information available in the plan and decide upon a package of flows for the next year, and based on that, the future years' flows documented.

Monitoring is important to assess whether the previous flow regime was effective, whether ecological objectives were met and what current threats are possible. The triggers may include failure of fish recruitment, poor water quality and/or a surrogate measure for both these classes of risk such as a flow threshold.

Step 5. Pull everything together = 10 Year Water Regime Plan

The 10 year water regime plan is then constructed from the elements in each of the previous steps. The objectives and outcomes of previous years would be reviewed annually but the plan itself should be reviewed every five years (mid-term review) with a larger more significant review at the end of each planning cycle (i.e. every ten years).

The process is an adaptive process which is summarised by the Figure 9.

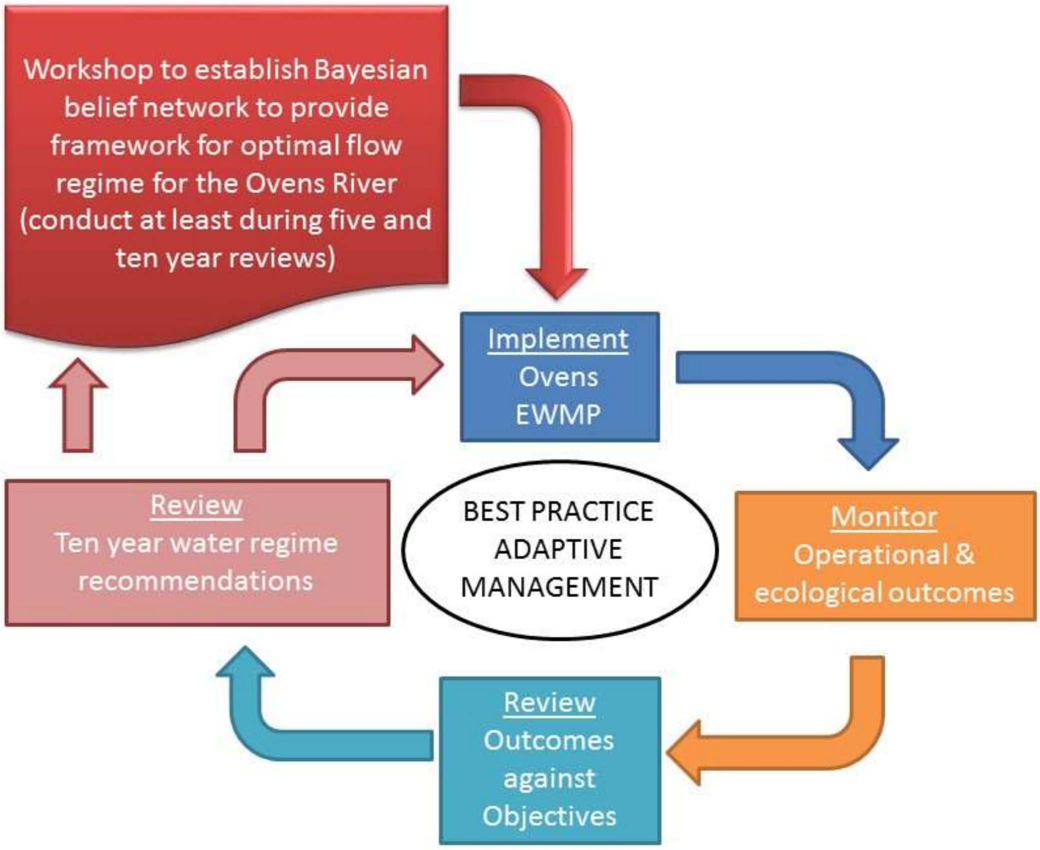


Figure 9: Adaptive management process for Ovens EWMP.

Table 18: An example ten year water regime for the Ovens River developed using the adaptive management procedure

Year	1	2	3	4	5	6	7	8	9	10
Focus objectives	Large-bodied iconic fish species									
Summer Low Flow	√	√	√	√	√	√	√	√	√	√
Summer (Low Flow) Fresh	√	√	√	√	√	√	√	√	√	√
Flow Fresh	√		√	√			√		√	√

7 RISK ASSESSMENT

A qualitative risk assessment was undertaken to:

- Understand and assign the level of risk posed by threats to the water-dependent ecological values of the Ovens system as this may impact on achieving the ecological objectives of this EWMP; and,
- Understand and assign the level of risk posed by the release and delivery of environmental water.

The relationship between likelihood (probability of occurrence) and the consequence (severity of the impact) provide the basis for evaluating the level of risk (Table 19).

Table 19: Risk rating based on likelihood and consequence of identified threats (adapted from NCCMA 2014).

		Consequence		
		Major	Moderate	Minor
Likelihood	Probable	High	High	Moderate
	Possible	High	Moderate	Low
	Improbable	Moderate	Low	Low

The threats were identified from documents produced by the NECMA (NECMA 2014a &b), the Campaspe River EWMP (NCCMA 2014), the most recent environmental flows assessment of the lower Ovens (Cottingham et al. 2008), and the output of a stakeholder workshop held as part of the development of this EWMP (see Appendix 2). The results from the risk assessment are presented in Table 20. Table 21 provides rationale for some of the assessments for likelihood or consequence ratings.

Table 20: Risk ratings assigned to identified threats to environmental flow objectives in the lower Ovens

Threat	Likelihood	Consequence	Risk (H, M, L)	Management / Mitigation Measure	Residual Risk
Threats to achieving the ecological objectives					
1. Release volume is insufficient in meeting required flow at target points	Probable (downstream of Wangaratta)	Moderate (summer) / Minor (winter)	H to M		
	Possible (upstream of Wangaratta	Moderate (summer) / Minor (winter)	M to L		
2. Current recommendations on environmental flow inaccurate	Possible	Moderate	M		
3. Releases cause water quality issues	Possible	Major	H	Ensure sufficient information available regarding catchment, stream and lake water quality is taken into account before releases.	M
4. Improved conditions for non-native species	Possible	Moderate	M		
5. Artificial instream structures (dam walls/weirs) - hypoxic water, cold water releases	Possible	Minor	L		
6. Artificial instream structures (dam walls/weirs culverts) – impede upstream movement of fish	Probable	Minor	M		

Threat	Likelihood	Consequence	Risk (H, M, L)	Management / Mitigation Measure	Residual Risk
7. Artificial instream structures (dam walls/weirs) – fill as sediment traps; create scour downstream	Possible	Minor	L		
8. Stocking of native fish – masking broader problems	Possible	Minor	L		
9. Recreational fishing – reduce numbers of target species especially during droughts	Possible	Moderate	M		
10. Grazing pressures on riparian vegetation	Probable	Minor	M		
11. Introduced species: Carp – impacting instream vegetation & whole of food web.	Probable	Moderate	H	Prepare and implement carp management plan	M
12. Introduced species: Gambusia/redfin – competition for food/habitat with small native species	Probable	Moderate	H	Prepare and implement pest fish management plan	M
13. Land use change (hobby farm increase – change in demand)	Possible	Minor	L		
14. Erosion (bank, slope, gully)	Possible	Minor	L		
15. Livestock access	Possible	Minor	L		

Threat	Likelihood	Consequence	Risk (H, M, L)	Management / Mitigation Measure	Residual Risk
16. Willows & other weeds	Probable	Moderate	H	Targeted and well executed plan for willow (and other weed) removal	M
17. Sedimentation	Possible	Minor	L		
18. Removal of large woody habitat	Probable	Moderate	H	These can be regulated by the CMAs Waterway Protection By-law. DELWP is developing guidelines to assist on this topic. NEWS action in the lower overs also includes not loss on instream timber from the lower Ovens	L
19. Stormwater – rubbish, urban run-off (contaminants) and waste	Probable	Minor	M	Stormwater plan already in place. Make sure plan implementation is ongoing, including maintenance of infrastructure	L
20. Temperature increase from willow removal (and lack of subsequent native revegetation)	Possible	Minor	L		
Threats to delivery of environmental water					
21. CEWH water holdings not available	Possible	Minor (70 ML small % of flow)	L		

Threat	Likelihood	Consequence	Risk (H, M, L)	Management / Mitigation Measure	Residual Risk
22. Storage operator maintenance works affect ability to deliver water	Possible	Minor	L		
23. Resource manager cannot deliver required volume of requested release pattern	Possible	Moderate	M		
24. Limited CMA resource to deliver environmental release	Improbable	Minor	L		
25. Cost of delivery exceeds available funding	Improbable	Moderate	L		
26. Not changing flow regime because of institutional inflexibility	Possible	Minor to Moderate	L to M		
27. Dumping of large rubbish causing flow impediment	Improbable	Minor	L		
28. Aging infrastructure (not all the structures instream serve a purpose. Some may be a hazard and/or impede flow)	Possible	Minor	L		
29. Insufficient maintenance of major infrastructure (dam release mechanisms fit-for-purpose)	Possible	Minor	L		

Threat	Likelihood	Consequence	Risk (H, M, L)	Management / Mitigation Measure	Residual Risk
30. Climate change leading to extreme low flows	Probable	Moderate	H	Employ climate change adaption strategies (currently untested)	?
31. Public perception counter to objectives (boat access removal of snags and altering riparian margins)	Probable	Moderate	H	Narrative document/film that communicates objectives of e-watering and benefits to fish and rest of ecosystem. Should reduce likelihood to Possible and Consequence to Minor	L
32. Increase in entitlement usage / expansion of irrigation	Possible	Moderate to High	H		?

Table 21: Rationale for selected risk ratings derived for threats to environmental flow objectives in the lower Ovens.

Threat	Rationale
1. Release volume is insufficient in meeting required flow at target points	Likelihood rating of Probable is for downstream of Wangaratta (Reach 5), Possible for upstream of Wangaratta (Reaches 1, 2, 3 and 4). Consequence rating of Moderate is for summer, Minor for winter.
3. Releases cause water quality issues	If a blackwater event occurs, the consequence could be major
4. Improved conditions for non-native species	Moderate consequence rating reflects impacts of carp and also Gambusia
5. Artificial instream structures (dam walls/weirs) - hypoxic water, cold water releases	Consequence minor due to small release volumes relative to river capacity in this system
8. Stocking of native fish – masking broader problems	Consequence minor due to mitigation measures already being employed by already marking stocked fish
9. Recreational fishing – reduce numbers of target species especially during droughts	Likelihood rating of Possible as although limits and restrictions are in place, they may need more enforcement
10. Grazing pressures on riparian vegetation	Assumes that many of the impacts are ongoing (i.e. not increased)
13. Land use change (hobby farm increase – change in demand)	There is a possibility that the demand for water could reduce as irrigated crop farms are taken over by hobby farms
14. Erosion (bank, slope, gully)	Assumes that many of the impacts are ongoing (i.e. not increased)
15. Livestock access	Assumes that many of the impacts are ongoing (i.e. not increased)
17. Sedimentation	Assumes that many of the impacts are ongoing (i.e. not increased)
18. Large Woody Habitat	Concern about community wanting easier boat passage. With education (as a form of mitigation) this may reduce to minor
19. Stormwater – rubbish, urban run-off (contaminants) and waste	Consequence rated as minor due to a stormwater plan, SEPP objectives, and regulation being in place, which should limit impacts. Similarly, temporal impacts likely to be limited to (mostly) just after storm events.
21. CEWH water holdings not available	Likelihood is climate dependent. Consequence influenced by the largely unregulated nature of the system and the relatively small percentage of total flow provided by 70 ML

Threat	Rationale
22. Storage operator maintenance works affect ability to deliver water	Consequence – Minor but dependent on time of year and input from elsewhere
23. Resource manager cannot deliver required volume of requested release pattern	Likelihood listed as possible because outlets cannot release pulsed volumes (when system is regulated) up to flow recs.
25. Cost of delivery exceeds available funding	Likelihood improbable within 10-year time frame

8 ENVIRONMENTAL WATER DELIVERY INFRASTRUCTURE

8.1 Constraints

8.1.1 Infrastructure and Operational Constraints

The environmental minimum flows specified in the Ovens System Bulk Entitlement are an obligation on G-MW and the outlet capacities of Lakes Buffalo and William Hovell are large enough to accommodate both passing flows and the usual range of consumptive demands. This means there is usually no competing needs for outlet capacity and passing flows are able to be delivered without any delay.

The small 70 ML holding of Commonwealth environmental water does not contribute to any infrastructure constraints. Instead, the main problem with the delivery of small volumes from either Buffalo or William Hovell is that it cannot be delivered in a precise manner. Minimum outflow constraints limit the ability to deliver the 70 ML entitlement from either Lake Buffalo or Lake William Hovell over a multiple day period as it is difficult to adjust the outlets for such small volumes. Only flow increments of around 20 ML/d are possible (G-MW, 2015 pers. comm.) with the current infrastructure.

The environmental entitlements at Lake Buffalo and Lake William Hovell can only be released (or accounted for) when the storages are not spilling. The main reason for this that to meet the requirements of a regulated release, flows must exit the outlet structures of a storage (i.e. a spill is considered to contribute to the unregulated flow regime).

The restriction policies in place for the Ovens System apply to both environmental and consumptive users. The 70 ML Commonwealth environmental water entitlement has only been delivered in full for 3 of the 6 years it has been in existence (up until 2015). A return to drought conditions similar to 2006-07 would likely see a level of restriction imposed such that no allocation of the 70 ML entitlement would be available.

Between July 2014 and end June 2019 Commonwealth environmental water is to be delivered as per the arrangements outlined in the exchange of letters between the Commonwealth Environmental Water Holder David Papps (dated 8/8/2014) and the NECMA Chief Executive Officer Neil McCarthy (dated 22 August 2014) and the Ovens 01 Watering Schedule agreed between the NECMA, the VEWH and the CEWH. These conditions are that entitlements be ordered from storage prior to a specific date (e.g. mid-June of each year), that they must be delivered during periods of regulated flow (in most years between November and May while consumptive flows are also being delivered), and that the release of the entitlement does not contribute to the inundation of public or private property (i.e. that delivery does not result in an overbank flow, and this is very unlikely with a 70 ML entitlement).

The outlet capacity at Buffalo limits the ability to delivery larger freshes (listed in Table 16) required by the system, these would need to be met naturally in both magnitude and timing. For instance, the water that is currently available via the bulk water transfer (which can deliver larger flows is in the Autumn, which misses the peak of larval production but will have useful roles in allow adult fish to regain condition and juvenile fish to grow before winter through boost in productivity.

8.2 Infrastructure recommendations

The primary recommendation is for additional streamflow monitoring sites so that losses in the River in the reaches downstream of the reservoirs can be quantified and small flows (low flows and low flow freshes) can be delivered with more confidence.

Although the operations at Lakes Buffalo and William Hovell can sometimes be quite coarse, there is no realistic opportunity to upgrade the dam release infrastructure.

Operations of the hydro power station at Lake William Hovell should be better documented and work done to better "tune" operations with environmental outcomes. There is limited documented information on the operations of the Hydropower Scheme on Lake William Hovell, which may represent a constraint on the system and water releases. Information is available directly from G-MW, but it is preferable to have documented information which describes how the hydro-power station will be operated under a range of reservoir level or inflow scenarios. Hydro operations are complicated by other reservoir operations and so working with the reservoir operators to document these issues is likely to be best way to fill the gap.

There is limited understanding of losses from in-channel flows as they travel downstream, especially downstream of Wangaratta due to the limited flow monitoring available. Flow losses occur in a non-linear manner and will depend on the time of year, the size of flow, antecedent conditions and also any interactions with groundwater that might exist. Additional flow monitoring during many different flow conditions will provide data to better understand and quantify these losses and at what proportion they occur under different flow rates. Initially, portable automatic logger systems (PALS) could be used to investigate how monitoring arrangements could be enhanced before long term monitoring sites are established.

8.3 Complementary actions

As described in Section 4.4, flow regime is a significant determinant of the condition of a waterway (Figure 4); however, there are many catchment and instream management actions that can impact or ameliorate impacts on that condition (Figure 5). Some of the potential impacts to the stream described in section 4.4 include: thermal impacts (e.g. cold water releases from the dams); stock access to the river and riparian zones; historical river management activities such as de-snagging, willow planting and channel improvement; urban and industrial encroachment within the riparian zone; and gravel extraction within the stream channel. Accordingly, complementary management actions to assist meeting the objectives of the environmental watering would include:

- Determining the extent of the impacts of cold water releases from Lake William Hovell and identify mitigating actions;
- Working with land managers to manage stock access to all waterways within the lower Ovens system and working towards rehabilitation of riparian zones through erosion control and revegetation works;
- Undertaking public education activities to ensure the community understands the importance of large woody habitat (snags) and work towards maintaining these habitats where they exist and creating them where they have been depleted;
- Undertake willow replacement activities (refer to page 32 and 63 for description of threat), taking care to avoid leaving banks bare and susceptible to erosion and slumping, as well as leaving the channel without shading from riparian vegetation; and
- Promote planning policy designed to reduce encroachment of urban and industrial impacts on the riparian zone and also ensure appropriate treatment of stormwater.

Additional actions identified through the stakeholder consultation and risk assessment include:

- use waterwatch volunteers to extend monitoring of quality and quantity of water both before and after environmental water is delivered;
- the management/control of pest animal species, particularly invasive fish species such as carp and eastern gambusia;
- removal of unnecessary barriers to fish migration and the provision of fish passage over barriers that cannot practically be removed; and
- where possible, attempt to ensure environmental flows and other discharges are directed to the needs of native species and do not favour or enhance pest species.

9 DEMONSTRATING OUTCOMES

The large-bodied 'iconic' native fish species have been identified as the 'umbrella goal' of the ecological objectives for the assessment of environmental flow releases. They are clearly intended to act as indicators of the overall health and condition of the lower Ovens system. Accordingly, monitoring of the waterways should focus on the fish fauna and also assess key ecosystem components such as macroinvertebrates, macrophytes, water quality, and physical condition. The three key ecological objectives, based on delivering the target flow regime, are identified in Section 6.2 and include:

- *Maintain condition of adult fish and survival of juveniles;*
- *Increase / maintain production of larvae; and*
- *Increase / maintain food availability for larval fish.*

Monitoring for these three objectives could be achieved under a single program, undertaken bi-annually. A fish sampling program using standard netting and electrofishing techniques, focusing on documenting fish condition and quantitative recording of fish abundance in each year class, would provide the data for assessment of the first two objectives. Analyses of that data would include time series analysis of average condition and year class numbers.

A sampling program for microcrustacea and other zooplankton, undertaken concurrently with the fish sampling, would allow assessment of the third ecological objective. Sampling would best occur post-spawning, allowing sufficient time for larvae to hatch and reach feeding stage. Quantitative sampling to assess changes in overall food availability may need to be adapted to suit habitat conditions and should be considered during the planning stage.

In addition to sampling to assess achievement of the umbrella objectives, sampling of other key ecosystem components will contribute to a greater understanding of each reach, including the provision of explanatory variables for the ecological assessment. Although each individual component is worthy of assessment, macroinvertebrates and water quality indicators have sampling and analysis protocols for Victoria and specific objectives for Victorian waterways (Government of Victoria 2003).

Further, there are extant monitoring programs such as the Victorian Water Quality Monitoring Network[7]; EPA Victoria's biological monitoring program[8] , and the MDBA Water Quality Monitoring Program. All these programs have sampling sites in or close to the reaches identified in this report that can be used as a base for annual or bi-annual assessment. Water quality monitoring could be extended using waterwatch volunteers both before and after environmental water is delivered.

The Victorian Environmental Flows Monitoring & Evaluation Program (VEFMAP) program being undertaken in number of northern rivers, including the Goulburn-Broken, Loddon and Campaspe has a defined approach and methods for the detection and evaluation of river-specific as well as State-wide outcomes from environmental flows (Chee et al. 2009). It would be sensible to incorporate the methods developed and learnings derived from VEFMAP within any monitoring program of the environmental flows within the lower Ovens system. VEFMAP is a standard program adopted across Victoria which allows the systematic assessment of environmental flows within Rivers. Using this system will allow direct comparison to other Murray-Darling rivers and learn from the VEFMAP investigations on these system. This approach includes developing the conceptual basis, variables selected, rationale for monitoring, and analytical needs (Chee et al. 2009). King et al. (2012b) also

[7] (http://data.water.vic.gov.au/monitoring.htm)

[8] (http://www.epa.vic.gov.au/your-environment/water/protecting-victorias-waters/how-epa-protects-freshwater-environments#Biological)

provides advice on the design and implementation of a monitoring program for assessing the effectiveness of environmental flows.

In addition to these monitoring requirements, Cottingham et al. (2008), and others have recommended the following specific investigations for the lower Ovens system:

- Continuous monitoring of DO concentration in the lower Ovens River (Reach 5) when flows fall below 65 – 85 ML/d. This will allow for delivery of freshes to improve water quality should DO concentration fall below 2 mg/L (McNeil & Closs 2007);
- Targeted investigations of discharge-velocity-DO relationships in each reach to confirm conditions under which stratification and low DO concentration conditions become a risk to ecosystem condition;
- Diurnal oxygen concentrations are also important to monitor as the potential overnight DO "sag" is really important for ecosystem condition and platypus populations, in particular (Serena, APC, pers. comm. 2015);
- Discrete flow events be monitored to confirm that flows are delivered as described and to account for any losses or gains due to variation in geomorphology and factors such as groundwater recharge or discharge;
- Studies/investigations into the reasons for the lack of macrophytes in the Ovens River, including basic inventories and studies of community structure and distributions;
- An assessment of angling pressures on native fish species;
- Monitoring the geomorphic change (bed diversity, channel form) and comparing results with the outputs of the SRA; and
- Routine macroinvertebrate sampling, with additional focus on habitat where the macroinvertebrate communities are likely to be sensitive to changes in hydrology and hydraulics – for example on logs that make up structural woody habitat submerged in the main channel. Sampling methods such as the use of 'snag bags' could be used (Growns et al. 1999).

10 KNOWLEDGE GAPS AND RECOMMENDATIONS

The Ovens River system is a relatively well-studied river but there are a number of knowledge gaps relating to delivery of environmental water or the ability of the system to respond ecologically to environmental releases. Recommendations include:

- Document the operations of the Hydropower Scheme: There seems to be limited documented information on the operations of the Hydropower Scheme on Lake William Hovell, which may represent a constraint on the system and water releases. Information is available directly from G-MW, but it is preferable to have documented information which describes how the hydro-power station will be operated under a range of reservoir level or inflow scenarios. Hydro operations are complicated by other reservoir operations and so working with the reservoir operators to document these issues is likely to be best way to fill the gap.
- Design and implement a monitoring program to determine flow losses: Understanding of losses from in-channel flows as they travel downstream, especially downstream of Wangaratta due to the limited flow monitoring available. Flow losses occur in a non-linear manner and will depend on the time of year, the size of flow, antecedent conditions and also any interactions with groundwater that might exist. Additional flow monitoring during many different flow conditions will provide data to better understand and quantify these losses and at what proportion they occur under different flow rates. Initially, portable automatic logger systems (PALS) could be used to investigate how monitoring arrangements could be enhanced before long term monitoring sites are established.
- Examine the range of water trade options to access new environmental water: Undertake an investigation to explore the range of water trade options that might exist within the system. Water trading may free additional sources of environmental water which is not currently exercised. What are the constraints and volumes available?
- Assess the current consumptive demands in the system: Undertake a desktop review the current consumptive demands in the system to determine what "slack" exists, particularly in the context of changing land use and agricultural practices and to explore the patterns of consumptive use to assess if there are opportunities for additional forms of environmental water (for example, the proposed "accumulation" rule for the pulsed release of the environmental minimum flow allocation).
- Conduct original research into the ecological responses of fish to environmental water releases: While there have been syntheses of the ecological responses of fish in the broader Murray Darling Basin (King et al 2012b; Koehn et al. 2014, Kingsford 2014), there needs to be original research into the responses of the 3 iconic species listed in the Management Goal to examine how their exact response to environmental water releases within the Ovens River. For instance, what are the limiting factors of spawning in the Ovens River and how do the delivered flows contribution to spawning and/or recruitment of the 3 icon species? This will help the NECMA to refine environmental water releases as well as help to understand better the role of environmental water in the conservation and management of this system and its flora and fauna.
- Undertake research into what role does the Ovens River system play in the Murray-Darling Basin: Studies to date have shown that the Ovens River is important for native fish but what are the contributions of the Ovens to the broader biodiversity and function of the Murray-Darling Basin? Does the mostly unregulated nature of the system mean that the Ovens contributes fish, invertebrates and other aquatic fauna along with water, sediments and nutrients to the Murray at higher rate than other systems? Could changes resulting from the increased take up of allocated water entitlement impact upon the ability of managers to deliver the flow regimes required?

Investigations could consider the role of current flow regimes (and those under full entitlement) in the Ovens and the implications of these contributions mean for flow management within the Ovens.

- Quantitatively assess the impacts of recreational fishing and estimate impacts of any increases: Promotion of the native fish species will be a positive environmental change for the ecosystem but this may lead to an increase in recreational fishing pressure on the system. Creel studies and other assessments of the angling pressures on native fish species should occur in parallel to the implementation of this plan.
- Develop a Bayesian network to assist decision-making and scenario testing for flows in the lower Ovens: Establishing a Bayesian network would address many issues that confront environmental flow management, including: modelling cause-effect relationships; accommodating missing data; flexibility in incorporating new data as it becomes available (including replacing expert knowledge with observational data); scenario testing; preservation of system knowledge; being readily understandable; and useful as a tool in educating people unfamiliar with a system (Hart et al. 2006; Westbury et al. 2006; Westbury et al. 2007; Chan et al. 2012). A useful way to approach the development of a Bayesian network would be to run an expert workshop to develop conditional probability tables for the network. The workshop would include NECMA, GMW, Bayesian and risk assessment experts and some fish ecologists, to come up with an ecologically beneficial release strategy for this water (which is cost-neutral to other stake-holders). The workshop would be preceded with briefing paper which examines what is known for the key iconic species within the Ovens River on their ecological responses to environmental water. King et al 2012b; Koehn et al. 2014, Kingsford 2014 have synthesised some of the available material on the species and ecological processes concerned from information across the basin but this could be extended for other species and also documenting the implications of the information for management of environmental water in the Ovens River.

11 ABBREVIATIONS AND ACRONYMS

BE	Bulk Entitlement
CEWH	Commonwealth Environmental Water Holder
CMA	Catchment Management Authority
DEPI	Department of Environment and Primary Industries
DSE	Department of Sustainability and Environment (Now DEPI in 2013)
EPBC	Environment Protection and Biodiversity Conservation Act 1999 (Cth)
EWMP	Environmental Water Management Plan
FFG	Flora and Fauna Guarantee Act 1988 (Vic)
GL	Gigalitre (one billion litres)
GMW	Goulburn Murray Water
ISC	Index of Stream Condition
MDBA	Murray-Darling Basin Authority (formerly Murray-Darling Basin Commission, MDBC)
ML	Megalitre (one million litres)
ML/d	Megalitres per day
SRA	Sustainable River Audit
VEFMAP	Victorian Environmental Flows Monitoring and Assessment Program
VEWH	Victorian Environmental Water Holder
VWMS	Victorian Waterway Management Strategy

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13 APPENDIX 1: SPECIES LISTING OF FLORA AND FAUNA ON THE LOWER OVENS SYSTEM

Common name	Scientific name	EPBC Status	FFG status	Vic status
Amphibians				
Southern bullfrog (ssp. unknown)	*Limnodynastes dumerilii*			
Barking marsh frog	*Limnodynastes fletcheri*			
Spotted marsh frog (race unknown)	*Limnodynastes tasmaniensis*			
Common spadefoot toad	*Neobatrachus sudelli*			
Brown toadlet (Bibron's toadlet)	*Pseudophryne bibronii*	NT	L	En
Plains froglet	*Crinia parinsignifera*			
Common froglet	*Crinia signifera*			
Sloane's froglet	*Crinia sloanei*			
Rugose toadlet	*Uperoleia rugosa*			En
Southern brown tree frog	*Litoria ewingii*			
Plains brown tree frog	*Litoria paraewingi*			
Peron's tree frog	*Litoria peronii*			
Growling grass frog	*Litoria raniformis*	Vu	L	En
Verreaux's tree frog	*Litoria verreauxii verreauxii*			
Pobblebonk frog	*Limnodynastes dumerilii dumerilii*			

EPBC Status: NT = Near threatened; Vu = Vulnerable. **FFG Status**: L = Listed under FFG. **Vic Status** = status on Advisory List of Threatened Fauna (DEPI 2014): En = Endangered

Common name	Scientific name	EPBC Status	FFG status	Vic status
Crustacea				
Freshwater shrimp	*Paratya australiensis*			
Inland River prawn	*Macrobrachium australiense*			
Common yabby	*Cherax destructor*			
Murray spiny crayfish	*Euastacus armatus*		L	

FFG Status: L = Listed under FFG.

Common name	Scientific name	EPBC Status	FFG status	Vic status
Reptiles				
Yellow-bellied water skink	*Eulamprus heatwolei*			
Broad-shelled turtle	*Chelodina expansa*		L	En
Common Long-necked turtle	*Chelodina longicollis*			DD
Murray River turtle	*Emydura macquarii*			

FFG Status: L = Listed under FFG. **Vic Status** = status on Advisory List of Threatened Fauna (DEPI 2014): En = Endangered; DD = Data Deficient;

Common name	Scientific name	EPBC Status	FFG status	Vic status
Mammals				
Platypus	*Ornithorhynchus anatinus*			
Water rat	*Hydromys chrysogaster*			

Common name	Scientific name	EPBC Status	FFG status	Vic status
Birds				
Black-winged stilt	*Himantopus himantopus*			
Cattle egret	*Ardea ibis*			
Northern mallard	*Anas platyrhynchos*			
Australasian pipit	*Anthus novaeseelandiae*			
Clamorous reed warbler	*Acrocephalus stentoreus*			
Azure kingfisher	*Alcedo azurea*			NT
White-bellied Sea-eagle	*Haliaeetus leucogaster*		L	Vu
Swamp harrier	*Circus approximans*			
Spotted harrier	*Circus assimilis*			
Musk duck	*Biziura lobata*			
Blue-billed duck	*Oxyura australis*		L	En
Hardhead	*Aythya australis*			
Freckled duck	*Stictonetta naevosa*		L	En
Pink-eared duck	*Malacorhynchus membranaceus*			
Australasian shoveler	*Anas rhynchotis*			Vu
Grey teal	*Anas gracilis*			
Chestnut teal	*Anas castanea*			
Pacific black duck	*Anas superciliosa*			
Australian shelduck	*Tadorna tadornoides*			

Common name	Scientific name	EPBC Status	FFG status	Vic status
Plumed whistling-duck	*Dendrocygna eytoni*			
Black swan	*Cygnus atratus*			
Australian wood duck	*Chenonetta jubata*			
Magpie goose	*Anseranas semipalmata*		L	NT
Australasian bittern	*Botaurus poiciloptilus*	En	L	En
Little bittern	*Ixobrychus minutus dubius*		L	En
Nankeen night heron	*Nycticorax caledonicus hillii*			NT
White-necked heron	*Ardea pacifica*			
White-faced heron	*Egretta novaehollandiae*			
Eastern great egret	*Ardea modesta*			Vu
Intermediate egret	*Ardea intermedia*		L	En
Little egret	*Egretta garzetta nigripes*		L	En
Black-necked stork	*Ephippiorhynchus australis*			
Yellow-billed spoonbill	*Platalea flavipes*			
Royal spoonbill	*Platalea regia*			NT
Straw-necked ibis	*Threskiornis spinicollis*			
Australian white ibis	*Threskiornis molucca*			
Glossy Ibis	*Plegadis falcinellus*			NT
Brolga	*Grus rubicunda*		L	Vu
Australian pratincole	*Stiltia isabella*			NT
Australian painted snipe	*Rostratula australis*	Vu	L	CE
Latham's snipe	*Gallinago hardwickii*		N	NT
Red-necked stint	*Calidris ruficollis*			
Common sandpiper	*Actitis hypoleucos*			
Red-necked avocet	*Recurvirostra novaehollandiae*			
Black-fronted dotterel	*Elseyornis melanops*			
Red-capped plover	*Charadrius ruficapillus*			
Double-banded plover	*Charadrius bicinctus*			
Banded lapwing	*Vanellus tricolor*			
Masked lapwing	*Vanellus miles*			
Red-kneed dotterel	*Erythrogonys cinctus*			
Silver gull	*Chroicocephalus novaehollandiae*			
Whiskered tern	*Chlidonias hybridus javanicus*			
Australian pelican	*Pelecanus conspicillatus*			
Darter	*Anhinga novaehollandiae*			
Pied cormorant	*Phalacrocorax varius*			NT

Common name	Scientific name	EPBC Status	FFG status	Vic status
Little black cormorant	*Phalacrocorax sulcirostris*			
Great cormorant	*Phalacrocorax carbo*			
Hoary-headed grebe	*Poliocephalus poliocephalus*			
Australasian grebe	*Tachybaptus novaehollandiae*			
Great crested grebe	*Podiceps cristatus*			
Purple swamphen	*Porphyrio porphyrio*			
Dusky moorhen	*Gallinula tenebrosa*			
Black-tailed native-hen	*Gallinula ventralis*			
Spotless crake	*Porzana tabuensis*			
Baillon's crake	*Porzana pusilla palustris*		L	Vu
Australian spotted crake	*Porzana fluminea*			
Buff-banded rail	*Gallirallus philippensis*			
Lewin's rail	*Lewinia pectoralis pectoralis*		L	Vu
Little pied cormorant	*Microcarbo melanoleucos*			
Eurasian coot	*Fulica atra*			

EPBC Status: En = Endangered; Vu = Vulnerable. **FFG Status**: L = Listed under FFG; N = Nominated for listing. **Vic Status** = status on Advisory List of Threatened Fauna (DEPI 2014): NT = Near threatened; Vu = Vulnerable; En = Endangered; CE = Critically Endangered.

14 APPENDIX 2: COMMUNITY CONSULTATION PROCESS FOR THE LOWER OVENS SYSTEM

Refer to stand-alone report.