Report of the Ovens Scientific Panel on the Environmental Condition and Flows of the Ovens River

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COOPERATIVE RESEARCH CENTRE FOR
FRESHWATER ECOLOGY

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Executive Summary

The Department of Natural Resources and Environment (DNRE) is overseeing a Bulk Entitlement conversion process for the Ovens Basin, with the aim of converting current water authority rights to water to Bulk Entitlements under the provisions of the Water Act (1989). A key feature of this process involves an assessment of current environmental conditions and identification of any current or potential impacts on environmental values associated with the regulation of flow within the river system. The broad environmental objective of the Bulk Entitlement conversion process is to ensure that current environmental values are protected and, where possible, enhanced.

The Ovens Basin Bulk Entitlement Project Group appointed a Scientific Panel (convened by the Cooperative Research Centre for Freshwater Ecology) to consider environmental issues and to provide independent advice on the opportunities that exist through the Bulk Entitlement Conversion Process to better protect and enhance existing environmental values associated with regulated waterways in the Ovens Basin. The Scientific Panel had two objectives:

1. To specify a regulated flow regime that will sustain and where possible improve the current environmental values, dependent on water flows in the Ovens Basin; and
2. Provide advice to the Project Group on the environmental benefits of a variety of management options and operational scenarios.

The representative reaches considered by the Scientific Panel were:

1. Buffalo River: Lake Buffalo to the Ovens River;
2. Ovens River: From the confluence with the Buffalo River to the confluence of the King River;
3. King River: Lake William Hovell to Edi;
4. King River: Edi to the Ovens River confluence;
5. Ovens River: from the confluence with the King River to the Murray River.

Some of the major tasks completed by the Ovens Scientific Panel while undertaking this project included:

- Integration of existing knowledge of the environmental condition of streams in the study area (including the considerable experience and knowledge of the Ovens system held by Panel members);
- Consultation with Goulburn Murray Water to clarify the operation of the system;
- An intensive field trip, used to assess environmental conditions at 22 sites across the study area;
- Consultation with local landholders to gain their perspective of the river system;
- Analysis of hydrological data to identify changes to stream hydrology that have occurred since the regulation and diversion of water for agriculture and urban supply;
- A series of workshops to develop a common understanding of the river system, important environmental values to be protected, and how these values may have been affected by regulation and other catchment activities;
- The development of recommendations for a flow regime that will protect or enhance the environmental values identified for the river system.

Flow Regulation

Flow in the Ovens, King and Buffalo Rivers is modified by three processes:

1. The presence and operation of Lake Buffalo and Lake William Hovell;
2. Progressive extraction of water for irrigation and town water supply; and
3. Changes to the form of the channel due to channelisation, anabranching, substrate and snag extraction and flood levees.

Examination of hydrological data indicated that regulation associated with the operation of the Buffalo and William-Hovell Dams does not affect the magnitude of floods in the Ovens and King Rivers, other than causing a slight delay of the flood peak if it arrives when the dams are empty.

The effects of current regulation on river flow are limited to the summer-autumn period in years with 'average' and ‘below average’ flows, a time when the natural flow regime is already low. This effect is less evident during wet years when summer-autumn flows are relatively high. Within this summer-early autumn timeframe, regulation results in an overall flow reversal in the Buffalo and King Rivers; early in the low-flow period, regulated flows are lower than natural and then switch to being much higher. The flow reversal is often exacerbated by the release of supplementary flows to the Murray River to relieve capacity restraints when supplying downstream irrigators.

While regulation has seen an increase in the summer-autumn low-flows in the Buffalo and King Rivers, the extraction of water for agriculture and urban supply has reduced the low-flow volumes in the Ovens River below Wangaratta.

Overall, the effect of regulation and diversions on the flow regime across the study area is mainly confined to low flow periods, resulting in changes to the depth of in-channel flows in the order of tens of centimetres.

Summary of environmental values associated with the Ovens River system

The Scientific Panel identified the following environmental values associated with the Ovens River system, recommending that they should be protected in the future:

- The Ovens River is one of the last largely unregulated rivers in the Murray Darling Basin and is particularly important as a reference against which to assess the state of other lowland rivers in the region;
- The natural flow regime (including both high and low flows) as it maintains geomorphological, biological and ecological processes;
- Habitat diversity that includes instream features such as abundant large woody debris, cobbles, riffles, pools, bars, anabranches, flood runners and the littoral fringe, and floodplain and wetland/billabong features in the nearby landscape;
- Threatened species (flora and fauna), including up to ten native fish species of State and national conservation significance and icon species such as Murray cod;
- Riparian vegetation, especially in the upper King River and the lower Ovens River, which may serve as a template for future restoration or rehabilitation efforts. The remnant riparian and floodplain vegetation also provides important habitat for threatened species (fish, birds, amphibians) whose natural habitat in the region has been greatly reduced since European settlement. This includes river redgum forest and box woodlands, and herb wetlands such as those occurring adjacent to the lower

section of the Ovens River. In particular, lowland riparian habitat is an important refuge for threatened native fish species such as Trout cod and Murray cod;
- Generally good water quality conditions, especially above Wangaratta, that supports river and wetland biota and increases the likelihood of success of river rehabilitation via habitat reinstatement;
- Connectivity between the river channel and its floodplain that maintains floodplain function;
- Links with the Murray River, with the Ovens being important for water yield, water quality and fish migration.

The protection of the above environmental values is consistent with the objectives of the Heritage Rivers Plan for the Ovens River and the priorities of the Northeast Catchment Management Authority (Northeast Catchment & Land Protection Board 1997). Protection of these values can, therefore, be used as a guide for setting environmental management plans at the local and regional level.

Summary of threats to environmental values

A large number of activities and processes pose threats of varying degrees to the environmental condition of the Ovens River system. This is not surprising given the broad range of activities and land use that occur across the study area. The threats to environmental values include those associated with flow and river management, agricultural and industrial practices and activity, natural ecological processes, and invasion by pest plant and animal species. Environmental threats may be summarised as:

- Rapid changes to water releases from the two dams that rapidly reduces the habitat available for biota;
- The potential for cold water releases from the dams in summer that may limit the biological activity or distribution of river biota;
- The potential for low or zero flows in lower river reaches due to concentrated pumping by diverters at weekends (this needs to be confirmed) or from water releases failing to meet irrigation demand;
- The release of supplementary flows to the Murray, which may send unseasonable biological cues to native biota;
- The removal of snags and the clearance of riparian vegetation that helps to stabilise stream bed and banks and provides instream habitat;
- The encroachment of willows that affect channel geomorphology and result in increased erosion, altered habitat, reduced biodiversity, and altered food quality for instream biota;
- Bed and bank works by local landholders and previous gravel extraction that has reduced stream habitat diversity and mobilised sediments in the river system;
- Natural bed and bank erosion (exacerbated by bed and bank works undertaken over many decades) that results in increased sediment loads in the river system;
- The infilling of pools by transported sediments, for example in the Ovens River below Myrtleford and the lower King River, that may smother instream habitat;
- Management of Tea Garden Creek, its weir and nearby levees, in a manner that disconnects the creek from its floodplain, reduces the variability of flow entering from the Ovens River and serves as a barrier to fish movement;
- The presence of the Lake Buffalo and Lake William Hovell that serve as barriers to fish movement;

- The presence of carp, trout and other introduced species that compete with, or reduce habitat condition, for native fish species;
- The dominance of weeds such as blackberry and willows over large areas that reduce riparian habitat quality;
- Grazing and watering of livestock in floodplain wetlands and billabongs that reduce water quality and habitat conditions;
- Minor eutrophication and pollutants from urban areas (e.g. Wangaratta) and industrial discharges that may result in less than expected macroinvertebrate families present or contribute to eutrophication downstream in Lake Mulwala.
- Ill-coordinated construction of levees throughout the system – particularly where other responses to high flow may be more ecologically sound.

Summary of the environmental effects of flow regulation
The effects of flow regulation on the ecological components of the river system may be summarised as:

- River hydrology has been altered, with changes mainly restricted to low-flow periods in average or dry years. This has resulted in increased summer-autumn flows in the Buffalo and King Rivers and reduced summer-autumn flows in the lower Ovens River (the latter increases the potential for reducing instream habitat during critical low—flow periods). A ‘flow reversal’ also occurs in the summer-autumn period, with lower than normal flows in early summer switching to higher than normal flows in late summer-autumn;
- River geomorphology remains largely unaffected by flow regulation;
- Water quality remains largely unaffected by flow regulation but has been affected by inputs of nutrients and organic pollution, presumably in runoff form agricultural and urban areas;
- The effect of flow regulation on aquatic vegetation is largely unknown and will prove hard to disentangle from other factors without a targeted study. Floodplain wetlands are likely to have been affected by isolation from the river channels (due to levees) and land management practices (e.g. livestock access);
- Macroinvertebrates are unaffected by river regulation in upstream areas. The decline in macroinvertebrate communities in downstream areas is probably due to multiple catchment impacts;
- Native fish populations, including threatened species, have been affected by dams and weirs that act as barriers to migration. The extent of reduced habitat availability due to lower than natural flows in the lower Ovens reach needs to be confirmed. The extent of cold water releases from Lake Buffalo and the potential for cold water releases from Lake William Hovell also requires confirmation, as does the potential risk of dispersing fish larvae by flows such as supplementary releases to the Murray River;
- The connection between the river channel and its floodplain has been largely unaffected by flow regulation by the dams. However, river-floodplain connections have been altered by the presence of levees in mid Ovens and lower King River reaches.

Flow and other management recommendations were, therefore, developed to ensure sufficient low-flows to maintain existing instream habitat, particularly for threatened fish species and other management actions that reinstate or improve habitat available for river and wetland biota.

Flow and associated management recommendations

Flow and river management recommendations were developed to maintain the current high environmental or ecological value of the Ovens system and to address a number of the threats to environmental values. In particular, the recommendations aim to protect:

- The natural attributes of the Ovens River, including the largely natural flow regime and the connection of river flows with surrounding floodplain. Given that the Ovens River is one of the few remaining lowland rivers in Victoria with a relatively natural flow regime, its protection must be considered as a high priority;
- Both the natural high flow and low flow events that are recognised as important attributes of the Ovens River.

As no specific flow recommendations are required for the high flow season (June through to October), other than to continue with current dam operations in a fashion that causes as little disruption to natural flows in the Buffalo and King Rivers as possible, flow recommendations have been based on low-flow exceedance data. In particular, the 95% exceedance flows were adopted to set low-flow limits that are likely to maintain habitat for native fish. Given the need for additional work to confirm the low-flow requirements of native fish, the flow recommendations should be considered as interim values only.

Flow targets for the representative reaches in the Ovens River system

Reach	Minimum Flow Target (ML/d)
Buffalo River - below Lake Buffalo	60
King River – William Hovell to Edi	20
King River – Edi to the Ovens River	40
Ovens River – Buffalo River to King River	154
Ovens River – King River to Lake Mulwala	140

In changing current regulation practices to meet environmental flow recommendations, priority should be given to the protection of the Ovens River below Wangaratta. Higher flows in the upper Buffalo and King Rivers in summer (especially if releases are colder than natural) increases the potential habitat available for introduced brown trout, which competes with native species. However, the opinion of the Scientific Panel is that increased summer flows in the upper reaches are likely to be less detrimental to the Ovens system as a whole, than the loss of habitat that might result from very low flows in the Ovens River below Wangaratta, which is known to support many threatened species.

The generally good condition of the Ovens River system could be improved further by actions that complement the safeguard of the largely natural flow regime. These include habitat rehabilitation works, implementation of existing catchment management and water quality strategies and a review of levees required to protect key infrastructure. The ongoing maintenance or improvement to environmental conditions in the Ovens River system will be bolstered by:

- Giving the lower Ovens River greater status and protection as a natural reference site and a site for scientific merit and study, and in light of its Heritage River status;
- Listing the lower Ovens River as a critical habitat for Murray cod in Victoria;
- Supporting ongoing attempts to re-establish Trout cod populations in the Ovens River;

- Removal of the weir on the Ovens River at Tea Garden Creek and pumping water to users;
- Removing the barrier on the Maloney's Creek;
- Taking care to avoid significant reductions in flow associated with weekend pumping by diverters;
- Undertaking instream habitat work, especially in reaches 2 and 3, to improve habitat for fish;
- Implementing the Ovens Basin Water Quality Strategy;
- Implementing the national carp management strategy within the Ovens River basin;
- Reviewing the status, policy, and criteria for levee construction, maintenance and removal.

The Scientific Panel was asked to consider the diversion of 5 GL as a contingency to supply water to irrigators near the Warby Range. This raises a number of potential environmental concerns. For example, to meet the extra demand without impacting on the security of supply of existing diverters may require an increase in the storage capacity of one or both dams. This will mean that a greater proportion of annual flow will be captured, which in turn can reduce the frequency of ecologically important flows (e.g. small to medium flow pulses important for maintaining instream habitat diversity and water quality). Extra demand and a further increase in summer flows also increase the likelihood of 'flow inversion' effects in the river system (higher than natural summer flows, lower than natural winter flows). Increased summer releases may also increase the severity or extent of any cold water releases from the dams and reduce the natural variability in the flow regime that is considered to play an important part in maintaining generally good stream conditions.

The Scientific Panel, as a first preference, recommends that the 'ecological icon' status of the present flow regime be recognised and that no further diversions be made from the Ovens system. If this is deemed unattainable, then the Panel recommends that any further water extraction from the Ovens River should be taken from high flow events (preferably at Wangaratta where the 5 GL diversion is a relatively small component of total flow) and pumped to an off stream storage, rather than by expansion of existing storages and increased discharge during the irrigation season. In this way, the flow regime will be protected by minimising the increased summer flows that already exist, and taking the 5 GL at a time when this volume is a relatively small part of the discharge in the river. Any diversions should only occur after possible impacts on flows in the Murray and associated wetlands (e.g. Barmah forest) are first considered.

Knowledge Gaps

Further investigations to fill key knowledge gaps are recommended to confirm the low-flow recommendations and to improve our understanding of the environmental condition of the river system. These include:

- Additional fish habitat surveys at very low flows to update environmental flow requirements in the Ovens Bulk Entitlements;
- Further investigation of cold water releases from the dams that have the potential to confound the effect of environmental flows, especially for fish.
- Investigation of changes to river flow, if any, that occur with concentrated pumping by diverters on weekends and at night;
- Further investigation to determine the factors that are affecting macroinvertebrate communities in the lower Ovens River, with particular attention to pollutants;

- A survey to provide information on the distribution or ecology of in-channel macrophytes and riparian vegetation. This will help to identify the recruitment requirements of woody riparian species, and assess the seasonal responses of in-channel macrophytes.

An important future consideration will be the establishment of a performance monitoring and assessment program to ensure that environmental values are protected and to assess the response of the river system to future management actions (e.g. riparian rehabilitation, additional winter diversion should this occur). While important components of the river system are already monitored (e.g. hydrology, water quality, biological health using macroinvertebrates), there is no routine monitoring for components such as geomorphological changes, fish, and aquatic or riparian vegetation communities. Responsibility for undertaking the various management actions and for assessing their effect will require negotiation between stakeholders such as the NECMA, DNRE, GMW, EPA and local communities.

Contents

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1 INTRODUCTION

The Department of Natural Resources and Environment (DNRE) is overseeing a Bulk Entitlement conversion process for the Ovens Basin, with the aim of converting current water authority rights to water to Bulk Entitlements under the provisions of the Water Act (1989). A key feature of this process involves an assessment of current environmental conditions and identification of any current or potential impacts on environmental values associated with the regulation of flow within the river system. The broad environmental objective of the Bulk Entitlement conversion process is to ensure that current environmental values are protected and, where possible, enhanced.

The Ovens Basin Bulk Entitlement Project Group considered that a Scientific Panel should be convened to consider the environmental issues and provide independent advice on the opportunities that exist through the Bulk Entitlement Conversion Process to better protect and enhance existing environmental values associated with the waterways. DNRE approached the Cooperative Research Centre for Freshwater Ecology (CRCFE) to convene and manage the Scientific Panel, which will identify the flows necessary to maintain or improve key environmental values. The Project Group will consider the Scientific Panel's advice, along with economic and social factors, when it determines the Bulk Entitlement for the Ovens Basin.

1.1 Project Objectives

The Scientific Panel had two objectives:

- To specify a regulated flow regime that will sustain and where possible improve the current environmental values, dependent on water flows in the Ovens Basin; and
- Provide advice to the Project Group on the environmental benefits of a variety of management options and operational scenarios.

This report meets the first of these objectives. The Scientific Panel has focussed its attention on the factors that contribute to current environmental conditions, and developed recommendations that aim to preserve or enhance the key ecological attributes of the river system. The advice of the Scientific Panel on management options and operational scenarios will be reported separately.

1.2 Structure of this report

Chapter 2 of this report provides an overview of the study area. The general approach used by the Scientific Panel to assess river and floodplain condition in the study area is outlined in Chapter 3. Information describing the current flow regime and how this has changed since river regulation began is provided in Chapter 4. Flow-related river ecology in the study area is summarised in Chapter 5, along with summaries of environmental values to be protected or enhanced and the threats to the environmental values. The recommendations of the Scientific Panel are presented in Chapter 6.

2 OVERVIEW OF THE STUDY AREA

The Ovens River Basin covers approximately 778,000 hectares and includes the Ovens, Buffalo and King River systems as well as Black Dog, Reedy and Indigo Creeks. The climate and rainfall varies dramatically across the catchment due to the broad range in elevation, from >1,500 mm per year in alpine areas to 400-500 mm per year on the lower floodplains (DWR 1989a and b). The Ovens River system is one of the least regulated rivers in the Murray-Darling Basin. Only two small impoundments have been constructed for water storage, Lake Buffalo on the Buffalo River and Lake William Hovell on the King River. The lower section of the Ovens River, from Wangaratta to the Murray River, has been designated a Heritage River because of the uniqueness of its riverine and floodplain habitat and its importance as a habitat for endangered fish such as the Murray cod (LCC 1991, DNRE 1997).

The Ovens River rises in the Great Dividing Range between Mt Feathertop and Mt Speculation and flows approximately 150 km to join the Murray River in the backwaters of Lake Mulwala. The river system can be divided into four distinct reaches: a confined headwater reach (gravel, pool-riffle bed), a confined valley reach, an upper anabranching reach (sand bed), and a lower anabranching reach (sand and clay bed) (OBWQWG 2000, Schumm *et al*. 1996).

Land across the Ovens Basin is dominated by native vegetation on public land (48%) and dryland cropping and grazing pasture (42%). The remaining land is used for a mixture of pine plantations (4%), irrigated horticulture and grazing (1%) and urban development (<1%) (OBWQWG 2000). Irrigated horticulture occurs predominantly along the fertile river flats of the King, Buffalo and Ovens Rivers. Crops such as tobacco and hops have been grown for over a century, but are now being phased out of production. Wine grapes have replaced tobacco as a major irrigated-agriculture crop as they provide a better return to farmers. The population of the catchment is approximately 45,000, of which 35% live in Wangaratta on the riverine plains.

The study area for this project includes the main lowland river channels and associated floodplain of the Buffalo, King and Ovens Rivers. The project brief identified four representative reaches to be considered by the Ovens Scientific Panel:

1. Buffalo River: Lake Buffalo to the Ovens River;
2. Ovens River: From the confluence with the Buffalo River to the confluence of the King River;
3. King River: Lake William Hovell to Ovens River, including Musk Gully Creek downstream of the diversion to Whitfield;
4. Ovens River: from the confluence with the King River to the Murray River.

Musk Gully Creek was excluded from consideration as bulk entitlements have recently been set for small urban supplies in the Ovens system (P. Bennett, pers. comm.). In addition, the volume diverted for small urban centres is relatively small and has been included in the modelling undertaken as part of this study.

After considering the features of the King River, the Scientific Panel decided that it should be considered as two reaches, (1) from Lake William Hovell to Edi, and (2) from Edi to the confluence with the Ovens River, recognising the different geomorphology of the two sections of the river. The representative reaches (Figure 1) considered by the Scientific Panel were, therefore:

6. Buffalo River: Lake Buffalo to the Ovens River;
7. Ovens River: From the confluence with the Buffalo River to the confluence of the King River;
8. King River: Lake William Hovell to Edi;
9. King River: Edi to the Ovens River confluence;
10. Ovens River: from the confluence with the King River to the Murray River.

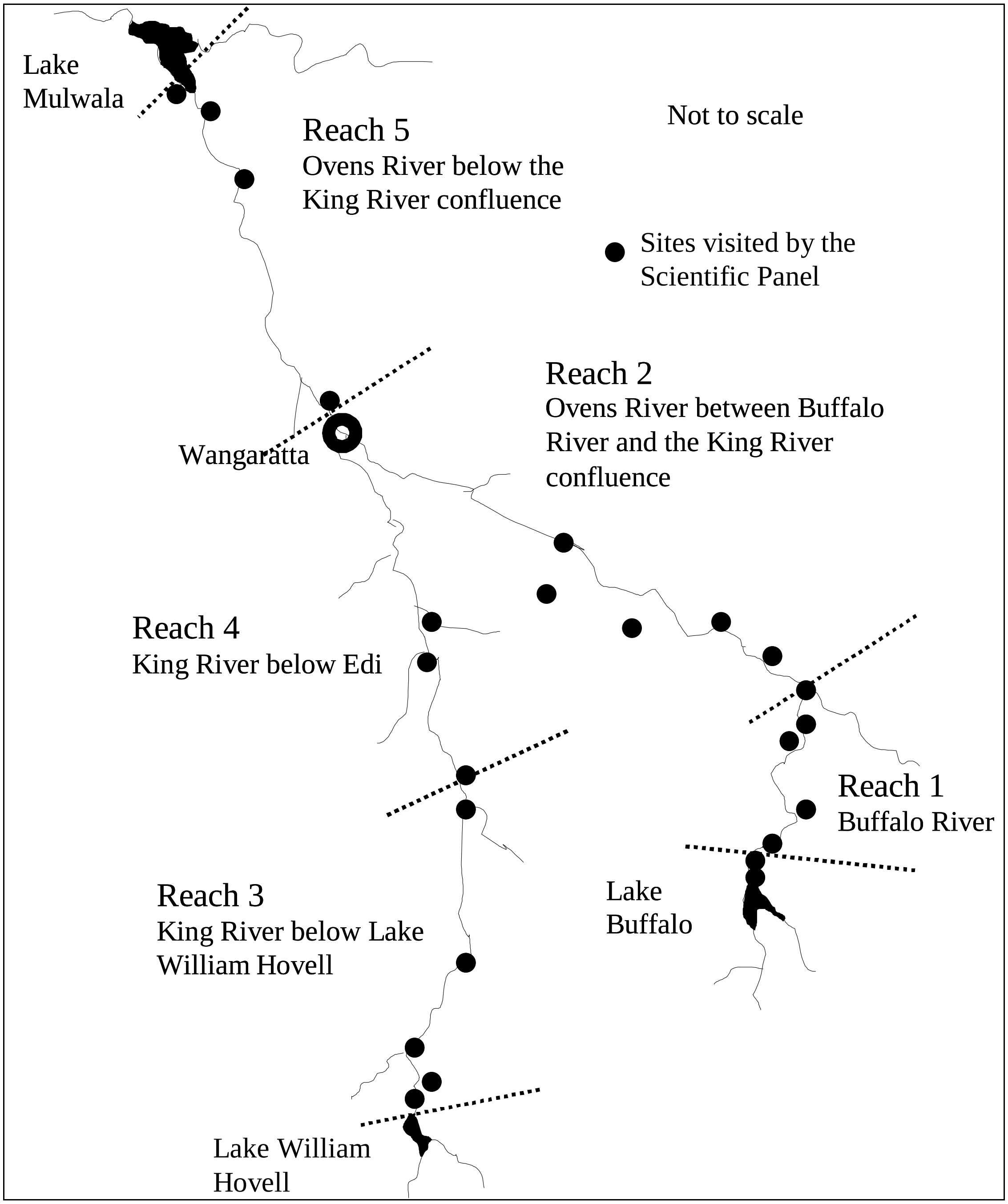


Figure 1: Ovens River representative reaches and sites visited by the Scientific Panel

3 SCIENTIFIC PANEL APPROACH

The Scientific Panel approach is essentially a rapid appraisal of the geomorphological and ecological condition of a riverine ecosystem by an interdisciplinary team that includes both local and scientific expertise. This approach has been employed within the Murray-Darling Basin on the Darling and Murray Rivers (Thoms *et al.* 1996 and 2000), the Campaspe River (Marchant *et al*. 1997) and the Murrumbidgee River (NSW EPA 1997; Murrumbidgee Expert Panel 2000), and on the Snowy River in Victoria (Snowy River Expert Panel 1996).

The advantages and limitations of the expert panel method have been reviewed by the NSW EPA (1997) and Swales and Harris (1995). Key strengths include:

- Synergies are gained from the interaction across scientific disciplines, and between scientists and managers;
- The process is relatively quick and inexpensive compared to many other environmental assessment methods;
- Relatively few field measurements are required;
- The process provides an opportunity for collaborative decision-making for river management within a framework of adaptive management.

Shortcomings of the scientific panel approach include:

- The method is mostly qualitative, so additional investigations may be required to confirm findings;
- Assessment is restricted to a limited number of sites that must be representative of the river system;
- The method can be limited by the expertise of the Panel members;
- As it is based on a brief view of the system at only one point in time (snap shot) Panel members must be aware of the variability of the system.

3.1 Ovens Scientific Panel Approach

The experience and expertise of the Ovens Scientific Panel is summarised in Appendix 5. All the Panel members have considerable experience in assessing the environmental condition of rivers in the Murray Darling Basin, particularly in the Ovens River catchment.

In order to undertake the assessment required by the project brief, the Scientific Panel developed a framework in which recommendations could be developed in a way that was consistent, easily understood, environmentally defensible and scientifically valid. This framework was based on:

- An understanding of ecosystem health, including important river and floodplain ecosystem components (e.g. fish or vegetation biodiversity or community structure), that may be affected by management decisions;
- Principles for assessing river condition and making recommendations to improve river health within a water management context, focussing on:
    - ➢ The natural diversity of habitats and biota within the river channel, riparian zone and floodplain should be maintained (and where possible enhanced);
    - ➢ The natural linkages between the river and the floodplain should be maintained;

  - ➢ Natural metabolic functioning of aquatic ecosystems, such as primary productivity and respiration, should be maintained.
- Assessing the river as a whole and operation of the river at the largest possible scale.

Further, elements of the natural flow regime, especially seasonality, should be retained as far as possible in order to provide or maintain a niche for native species and maintain the natural functions of the river system.

Some of the major tasks completed by the Ovens Scientific Panel while undertaking this project included:

- Integration of existing knowledge, from both historical and current information on the environmental condition of streams in the study area (including the considerable experience and knowledge of the Ovens system held by Panel members);
- Consultation with Goulburn Murray Water to clarify the operation of the system;
- An intensive field trip, used to assess environmental conditions at 22 sites across the study area;
- Consultation with local landholders to gain their perspective of the river system;
- Analysis of hydrological data to identify changes to stream hydrology that have occurred since the regulation and diversion of water for agriculture and urban supply;
- A series of workshops to develop a common understanding of the river system, important environmental values to be protected and how these values may have been affected by regulation and other catchment activities;
- The development of recommendations for a flow regime that will protect or enhance the environmental values identified for the river system.

3.2 Reach Assessment Methodology

The Scientific Panel visited the representative reaches over the three days of 22nd-24th November 2000 (Table 1). The visit coincided with relatively high flow in the river system, representative of a 1-year average return interval. The high river flows at this time precluded access along much of the lower reach of the Ovens River (Reach 5), and the Scientific Panel was unable to view the system under low flow conditions. The Panel provided an assessment of each reach based on:

- The knowledge of individual Panel members of conditions within the reach;
- Additional information on the river system obtained from the scientific literature and other published reports, and data held in natural resource databases;
- Advice and information provided by other relevant experts contacted by Panel members;
- Joint inspection of a range of sites within each reach. These included a detailed examination of one or more sites within the reach and visual observation of a number of sites (Table 1);
- Meetings with local landholders and reservoir operators;
- Examination of hydrographic records and flow modelling undertaken by DNRE using a REALM model of the Ovens system.

Table 1: Sites visited by the Scientific Panel, 22nd – 24th November 2000.

Reach	Site	Location
1. Buffalo River – Lake Buffalo to the Ovens River confluence	B1	Buffalo River at Lake Buffalo
	B2	Buffalo River at upstream gauging station
	B3	Buffalo River at McGuffies Reserve
	B4	Buffalo River at Ronaldi's Merriang
	B5	McGuffie farm near Buffalo Creek
2. Ovens River – Buffalo River confluence to King River confluence	B6	Ovens River at Buffalo River confluence
	O3	Ovens River at Tarrawingee
	O4	Ovens River at Whoroully (Rocky Point)
	TG1	Tea Garden Creek at Ovens River
	TG2	Tea Garden Creek near Home Station
3. King River – Lake William Hovell to Edi	K1	King River at Lake William Hovell
	K2	King River at upstream gauge
	K3	King River at Cheshunt south (canoe landing)
	K4	King River at Cheshunt south (long riffle)
	K5	King River at Cheshunt gauge
	K6	King River at Edi cutting
	K7	King River at Edi gauge
4. King River – Edi to the Ovens River confluence	K8	King River at Moyhu
	K9	King River at Docker
	K10	King River at Oxley
5. Ovens River – King River confluence to the Murray River confluence	O1	Ovens River at Peechelba
	O2	Ovens River at Lake Mulwala

4 FLOW REGULATION IN THE OVENS RIVER SYSTEM

Average annual streamflow in the study area ranges from approximately 200 GL in the King River, to approximately 440 GL in the Buffalo River, 1,150 GL in the Ovens River at Rocky Point and 1,750 GL in the Ovens River below Wangaratta (DWR 1989b). In an assessment of streams across Victoria, Hughes and James (1989) found that flows in the Ovens and Buffalo Rivers had a relatively low variability when compared with other streams, especially those in the more arid areas of western Victoria.

Flow in the Ovens, King and Buffalo Rivers is modified by three processes:

1. The presence and operation of Lake Buffalo and Lake William Hovell;
2. Progressive extraction of water for irrigation and town water supply; and
3. Changes to the form of the channel due to channelisation, anabranching, substrate and snag extraction and flood levees.

The operation of Lakes Buffalo and William Hovell to provide irrigation and town water supply are discussed in the following sections. Changes to river form (geomorphology) and the effect of flood levees are discussed in Chapter 5.

4.1 Operation of Lake Buffalo

Lake Buffalo is located on the Buffalo River approximately 20 km south of Myrtleford. The dam was completed in 1965 and has a capacity of 24,000 ML, a surface area at Full Supply Level (FSL) of 340 hectares, and a catchment area of approximately 1,060 km^2. The FSL is 264.4 m AHD. The dam has a height of 31 metres and two spillways, an Ogee Crested concrete gated spillway (110,000 ML/d capacity at Imminent Failure Flood, IFF) and an uncontrolled earthen chute (61,000 ML/d at IFF). The dam has a dead storage of 5,000 ML. The volume of the dam is small compared with an annual average flow 440 GL; the maximum recorded inflow of 54,000 ML/d that occurred in 1993 would have filled the dam from empty in approximately 12 hours. Thus the dam has little influence on annual flow volumes in the Buffalo River.

Releases from the dam are via 3 mechanical gates and 2 gate valves. The valves are set at 256.3 m AHD (to the centre) and this level is 4.5 m below the gated spillway sill (260.8 m AHD). Valve capacities are 600 ML/d and 200 ML/d respectively (M. O'Brien, pers. comm.). The mechanical gates are used to regulate the storage above 260.8 m AHD; this corresponds to 13,690 ML in storage. Operation of the gates poses difficulty for GMW as they may be clogged with small debris if opened only a small amount (e.g. less than 15 cm), or clogged with large woody debris if opened more than 0.5 m. Being jammed by large wood is the most problematical as a considerable amount of water may be lost before the gates are freed and closed.

Summer flows are released to meet irrigation demand (150 – 200 ML/d), to ensure the water supply for Wangaratta, and to provide supplementary flow (around 300 ML/d for 3-4 weeks) for the Murray River if additional resources are required, for example in South Australia. GMW aims to draw the storage down to a minimum of 6,000 ML by the end of April each year. After April, flow from the dam is reduced to 20 – 50 ML/d as the storage is filled to 13,690 ML. In other words, water is released from the dam through the valves that are kept open. The inflow to the dam is greater than this release, and the dam gradually fills. The amount released from the valves is a function of the depth of water in the reservoir (the head above the valves), so the volume released from the valves progressively increases from about 20 ML/d to about 50 ML/d. Gates are kept open for this period to reduce wear (i.e. the gates are lifted up out of the flow). When the dam has reached its capacity of 13,690 ML, the valves are closed and any extra flow simply spills over the sill.

GMW monitor storage levels and inflows during the spring. The operational objective is to ensure that the storage is full by mid November when demands may equal inflows under dry conditions. The decision to fill the storage by partially closing the gates is deferred as long as possible to reduce unnecessary gate operations. GMW use inflow criteria and target filling curves to regulate flows to fill the storage by the target filling date. The maximum rate of rise in the storage level is 0.1m/day in September. This corresponds to an increase in storage, and reduction of downstream flow of about 280 ML/d. The inflow criteria to trigger filling operations in September is about 500 ML/d, so the maximum effect of regulation to fill the storage is to reduce flows from about 500 ML/d to about 200 ML/d. Overall, the major effect of Lake Buffalo may be characterised as:

- Flow in the Buffalo River remains relatively constant between February and April, instead of fluctuating at a low stage (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).
- Flow released from the dam is reduced from May until the dam fills to 13,690 ML. This situation may persist from one week to a month, depending on inflow. 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 (usually within a few weeks).

4.1.1 Extraction of water from the Buffalo River

There are 76 farmers who are licensed to extract 4,261 ML of water from the Buffalo River. However, only about 20% of this volume is usually extracted due to factors such as the change in irrigated landuse from tobacco (water applied at approximately 3 ML/hectare) to grapes (water applied at approximately 1.5 ML/hectare) (J. Baker, GMW, pers. comm.). Small volumes of water may occasionally be extracted for application as mist to avoid damage to grape crops by frosts.

Water is released from Lake Buffalo and from Lake William Hovell to maintain targeted minimum flow requirements of 150 ML/d at Ovens River at Rocky Point, 50 ML/d at Ovens River at Wangaratta and 20 ML/d at King River at Docker Road Bridge. Additional passing flows may be required to supplement the River Murray at Lake Mulwala. Factors which influence the release requirements from storage to meet the flow targets include, irrigation demand from licenced diverters, losses from the river, inflows from the Ovens River upstream of the Buffalo River, and inflows from the tributaries.

Each season an Operations Plan is prepared by the GMW Production Management Unit in Tatura. This plan establishes the broad operational objectives for the Ovens Basin for the current irrigation season. The plan is prepared early in the season and updated several times to take account of changed storage and catchment conditions through the season. The seasonal release patterns identified in the plans are based on water availability, storage releases and monitored flows at the reference gauging stations in previous seasons.

Diverters from the Buffalo and King Rivers and the regulated reaches of the Ovens Rivers are required to order water from GMW through Waterline. Their water orders are collated on the database housed on the Shepparton Diversions office computer. Flow summaries of ordered water are provided to the Wangaratta Diversions office each Monday, Wednesday and Friday and these are reviewed to understand trends in irrigation demand. This information is considered together with daily observations from the river gauging stations, weather forecast and operations plan to determine if the releases need to be increased to meet the passing flow requirement or decreased to conserve water in storage. Minor adjustment of storage releases is avoided where possible.

4.2 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, and has a capacity of 13,700 ML and a surface area of 113 hectares at FSL, with a catchment area of 331 km^2. The height of the main dam is 33 metres. The dam has a free-flow overfall spillway with a capacity of 97,900 ML/d.

The dam usually fills in August to early September each year. Water is released over summer and autumn for downstream use to achieve a target capacity of 2500 ML by the end of April. The lake has a dead storage volume (at 389.7 m AHD) of 1,000 ML. GMW makes an estimate of probable irrigation demand in November and subsequent months of each year, including the possible supplement to the Murray System. A minimum of 30 ML/d is maintained as a ‘riparian flow’ to ensure flow in the King River at Docker remains above 20 ML/d, and flow in the Ovens River at Wangaratta remains above 50 ML/d so that water may be extracted for urban supply (releases are made from Lake Buffalo and Lake William Hovell to ensure this). Water is also released at the end of the irrigation season to provide supplementary flows to the Murray River.

FSL of Lake William Hovell is 408.1 m AHD. Water is released through the outlet tower that has two outlets, one at RL 392.7 m AHD and the other at RL 389.6 m AHD. The 900 mm diameter outlet conduit allows the release to the King River through the cone valve or alternatively via a hydro-electric power station. Although each outlet valve has a 300 ML/d capacity, the capacity of the outlet conduit is 520 ML/d. The power station has a maximum discharge of 520 ML/d via its turbines. The maximum capacity of the cone valve is 320 ML/d. Thus the maximum flow that can be released when the dam is not spilling is 520 ML/d under current operations.

The 1.6 MW hydroelectricity power station at the dam is operated remotely by the Great Southern Power Company from Young, NSW. The power station requires a minimum flow of 120 ML/d to operate. The power station can draw on water when levels in the dam are within 80 mm of FSL, potentially varying flows from 120 to 480 ML/d over short time periods. Typically, discharge is varied between 120 – 240 ML/d (N. Dewhurst, pers. comm.). 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. The times when the power station can affect its 80 mm fluctuations are quite limited, and do not generally coincide with the irrigation season. Power generation is more profitable by day (peak rates), and so flows are usually higher by day.

Releases may potentially result in a 200 mm height change in the King River below the dam, and this effect is progressively dampened downstream; the next tributary enters the King River only 5 km below the dam wall. Ramping up from 80-120 ML or down from 120-80 ML only occurs in the irrigation season.

Irrigators order water via a Water Line managed by GMW. The lead time is nominally 4 days but farmers operate on a 1-day ordering time to allow increased flexibility. Watering may be intermittent for grapes, but will always be synchronised amongst growers wanting to spray against frost, whether early in the irrigation season (for grapes) or at the end of the season (for tobacco). Boggy Creek has a water storage co-operative; this is the main area of development for grapes.

The effects of Lake William Hovell on flows in 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.

4.2.1 Extraction from the King River

Irrigation demand in summer is generally in the order of 60 – 140 ML/d to supply 98 diverters who are licensed to pump 11,275 ML from the river. However, only 30% of the licenced volume is extracted in an average year. There is anecdotal evidence that peak irrigation demand generally occurs on weekends when the cost of electricity for pumping is lowest, and that concurrent pumping by diverters can significantly reduce flow in the King River. It was not possible to assess the extent of reduced flows due to weekend pumping, as the largest reductions are most likely to occur in the lower reaches of the river where the stream gauging is limited (there are no gauges below Docker Rd Bridge). Flow in this river section is also influenced by tributaries such as Boggy and Hurdle Creeks, and the anabranching nature of the river. Separating the effects of weekend pumping by diverters from the natural fluctuation of flow will require a specific investigation.

The operational approach to water extraction from the King River is described in section 4.1.1.

4.3 Ovens River REALM model

Despite its limitations (see discussion in Appendix 1), the current Ovens River REALM model (SKM 1998) provides the best available representation of the Ovens River basin operations, inflows, demands and losses. This model is currently being used as a tool in the bulk water process to develop guidelines for converting existing rights to water into bulk entitlements. The Ovens Scientific Panel used model version OVENF020.SYS as it was readily available and could provide data with which to compare relative changes to the flow regime with varying levels of demand. While the REALM model, which has a weekly time step, is the best available tool for assessing the effects of changes to the flow regime, daily flow models are preferred when considering environmental flow requirements. Models with a weekly time step are likely to simplify the variability that may exist in a river system, especially at low flows. In this case, the REALM model overestimates the current flow regime during low-flow periods (i.e. actual flows are less than modelled data suggest).

4.4 The effects of regulation on river flow regimes

The effects of flow regulation on river hydrology were assessed by comparing the modelled natural with the current flow regime using data generated by the Ovens River REALM model. Current diversions are generally less than the licensed entitlements (diversions often represent only 20-30% of licensed volumes). Additional scenarios that were considered were flows in the river system if the full entitlement (Full Entitlement) was diverted for irrigation, and full entitlement plus 5 GL diverted from the Ovens River below Wangaratta as part of a scenario to provide water for irrigators in the Warby district (Full + 5GL).

Time series plots, flow duration curves, and mean monthly flows for each river reach are presented in Appendix 2 and selected examples are presented below to support the following discussion. The selected examples were for the period 1986 to 1993, as the actual irrigation demand during this period more closely matched the modelled demand, than did the period 1980 to 1985.

Regulation associated with the operation of Lake Buffalo and Lake William-Hovell does not affect the magnitude of floods in the Ovens and King Rivers. This can be seen by comparing the annual exceedance probability (AEP) of a partial duration series of flows (Figure 2), which compares all flows greater than 20,000 ML/d for the regulated and unregulated cases. It can be seen that the two series are essentially identical. Similarly, other regulation scenarios (e.g. Full Entitlement) similarly produced no change in the flood peaks. The only effect of the dams on flooding is expected to be a slight delay of the flood peak if it arrives when the dams are empty.

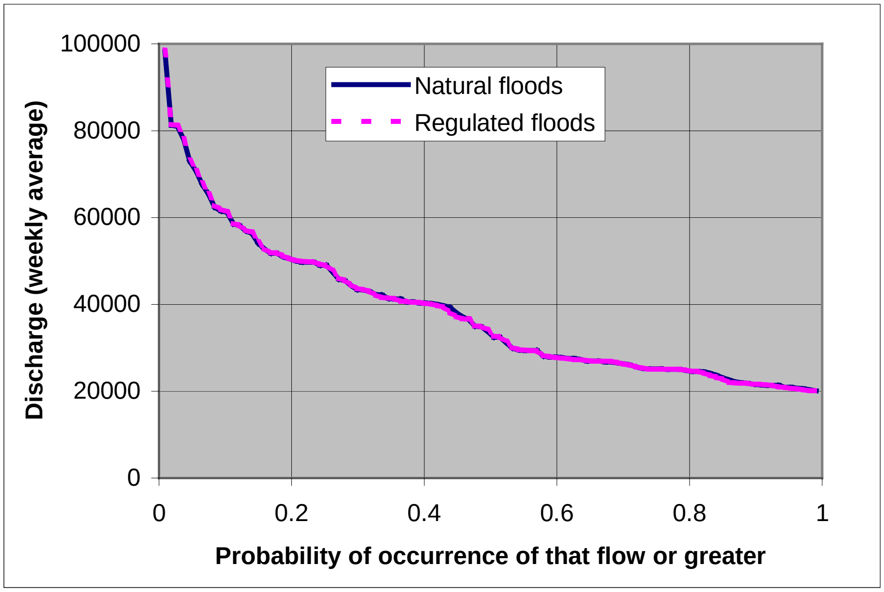


Figure 2: Probability of exceedance for flows greater than 20,000 ML/d for estimated natural and regulated flows (for period 1980 to 1993)

The effects of current regulation on river flow (as indicated by the upstream site on the Buffalo River and the downstream site of the Ovens River at Mulwala – Figures 3-6) are limited to the summer-autumn period in years with 'average' and ‘below average’ flows, a time when the natural flow regime is already low. This effect is less evident during wet years when summer-autumn flows are relatively high and demand for irrigation water is reduced. This seasonal restriction and restriction to average but not wet years appears to be true throughout the river, as it holds for both upstream and downstream sites.

Within this summer-early autumn timeframe, regulation results in an overall flow reversal; the hydrograph for natural flows decreases throughout the early part of summer, then remains low, filling rapidly with the onset of autumn. In contrast, the hydrograph for regulated flows decreases very sharply at the beginning of summer, flows remain low for 1-2 months then increases in late summer-early autumn. Unlike the natural flows, the regulated hydrograph increases much more gently in autumn. Thus early in the low-flow period, regulated flows are much lower than natural and then switch to being much higher: hence, 'flow reversal'. The flow reversal is often exacerbated by the release of supplementary flows to the Murray River to relieve capacity restraints when supplying downstream irrigators. The supplementary releases increase flows by 300-400 ML/d and last for approximately 3 weeks in March/April.

The three modelled scenarios (Current, Full Entitlement, Full Entitlement + 5GL) show that these three intensities of regulation have very similar effects on hydrograph shape (i.e. have similar temporal and flow magnitude effects). Modelling also shows that the impact of progressively increasing regulation (i.e. from Current to Entitlement to Entitlement +5GL) is much greater at the bottom of the system than at the top. At Lake Buffalo, the hydrographs modelled for the three scenarios are generally indistinguishable, and in only one year out of eight between 1986 and 1993 (in 1988) was the increasing intensity noticeable. In contrast, at the bottom of the Ovens system, the three hydrographs were readily distinguishable in all years when flow reversal occurred.

The effect of changes to the flow regime on river stage height was assessed by examining modelled low-flow (November to May) exceedance data (Table 2; Appendix 2) and identifying the exceedance flow that represented the greatest relative difference between natural and current flows. The difference in the respective stage heights at the selected flow exceedance was then noted (stage height data supplied by Thiess Environmental Services; modelled weekly flows were divided by 7 to estimate daily flow). For example, the greatest relative difference between natural and current low flow regime in the Buffalo River occurred at the 55% exceedance flow, with the current flow regime increasing river stage height by up to 9 cm when compared with natural. Similarly, the current flow regime has increased river height in the King River at Cheshunt by up to 18 cm at very low flows (99% exceedance). However, water levels in the Ovens River below Wangaratta have decreased by up to 8 cm during low-flow periods (95% exceedance flows). It should be noted that these figures represent average deviations based on weekly data. As discussed in sections 4.1, 4.2 and Appendix 1, short-term variability may result in larger fluctuations in river levels than indicated in Table 2.

Because the REALM model tends to overestimate the magnitude of low flows in the current flow regime (see discussion in Appendix 1), differences in stage height were also assessed by comparing natural modelled and gauged data, rather than modelled current data (Table 3). The results indicate that the increases to river heights in the Buffalo and King Rivers were less than suggested by modelled current regime, but that diversions decrease the water levels in the Ovens below Wangaratta by up to 11 cm.

Based on available data, the effect of regulation and diversions on the flow regime across the study area are mainly confined to low flow periods, resulting in changes to the depth of in-channel flows in the order of tens of centimetres. The potential ecological effects of these changes are considered in Chapter 5.

Table 2: Relationship between flow and stage height for low flow periods (November to May), based on modelled data for the natural and current flow regimes (1980 and 1993).

	Natural		Current		Maximum Difference (cm)	Flow Exceedance of maximum relative difference (percentile)
	Flow (ML/d)	Stage Height (m)	Flow (ML/d)	Stage Height (m)		
Buffalo River	196	0.711	322	0.805	9	55%
King River at Cheshunt	1	0.004	30	0.187	18	99%
King River at Docker Rd Bridge	14	0.317	38	0.399	8	99%
Ovens River at Rocky Point	280	0.647	380	0.722	8	80%
Ovens River below Wangaratta	140	0.611	71	0.536	-8	95%

Table 3: Relationship between flow and stage height for low flow periods (November to May), based on modelled natural data and gauged data (1980 and 1993).

	Natural		Gauged		Difference (cm)	Exceedance Flow of Maximum Deviation (percentile)
	Flow (ML/d)	Stage Height (m)	Flow (ML/d)	Stage Height (m)		
Buffalo River (403220)	103	0.607	130	0.639	3	80%
King River at Cheshunt (403227)	1	0.004	11	0.059	6	99%
King River at Docker Rd Bridge (403223)	87	0.510	101	0.532	2	75%
Ovens River at Rocky Point (403220)	280	0.647	305	0.667	2	80%
Ovens River below Wangaratta (403242)	80	0.545	16	0.440	-11	99%

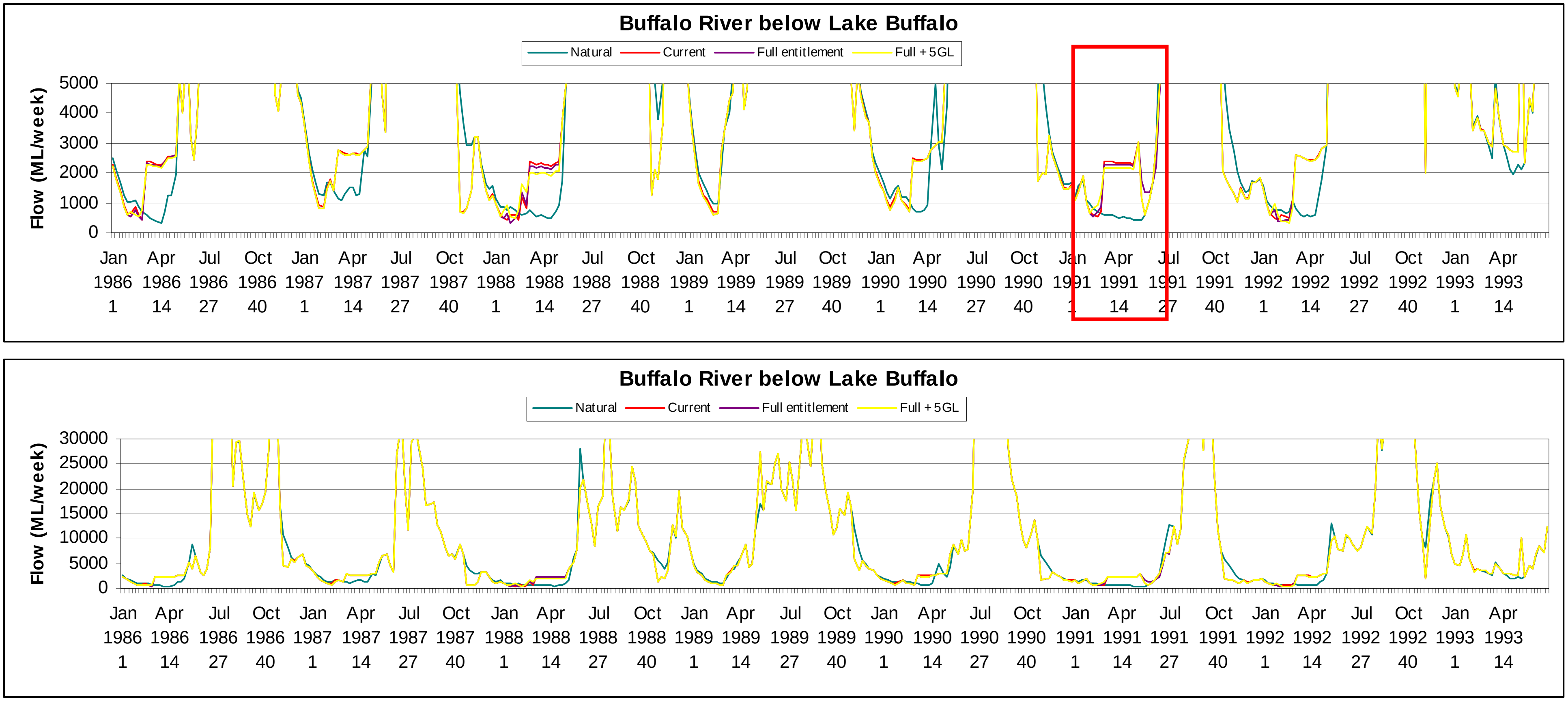


Figure 3: **Time series plots of current and natural flows in the Buffalo River (403220), 1986-1993. Note the different scales used to emphasise relative differences during low flow periods. The box on the plots emphasises the period when regulation has the greatest effect on the natural flow regime.**

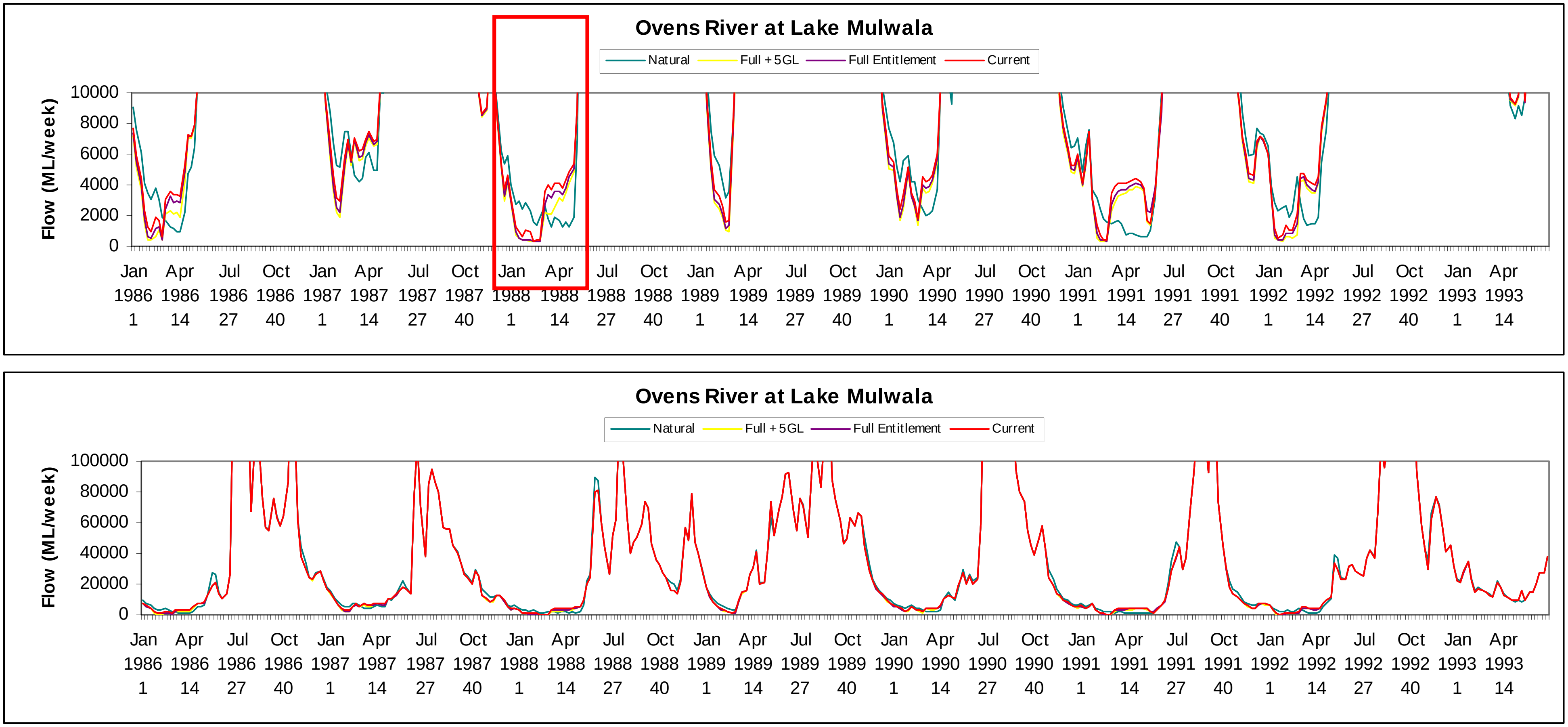


Figure 4: **Time series plots of flow in the Ovens River at Lake Mulwala, 1986-1993. Note different scales to emphasise relative differences during low flow periods. The box on the plots emphasises the period when regulation has the greatest effect on the natural flow regime.**

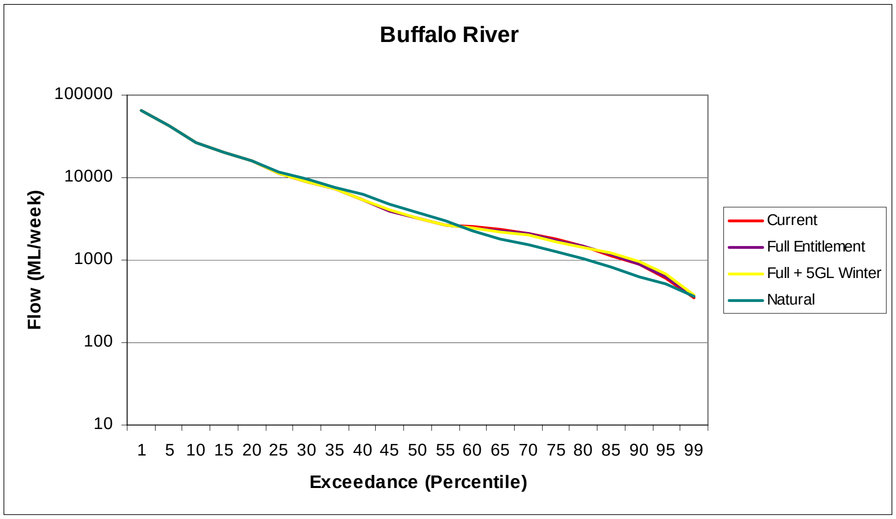


Figure 5: Comparison of modelled natural with current and potential future water demand from the Buffalo River (site 403220), 1980-1993

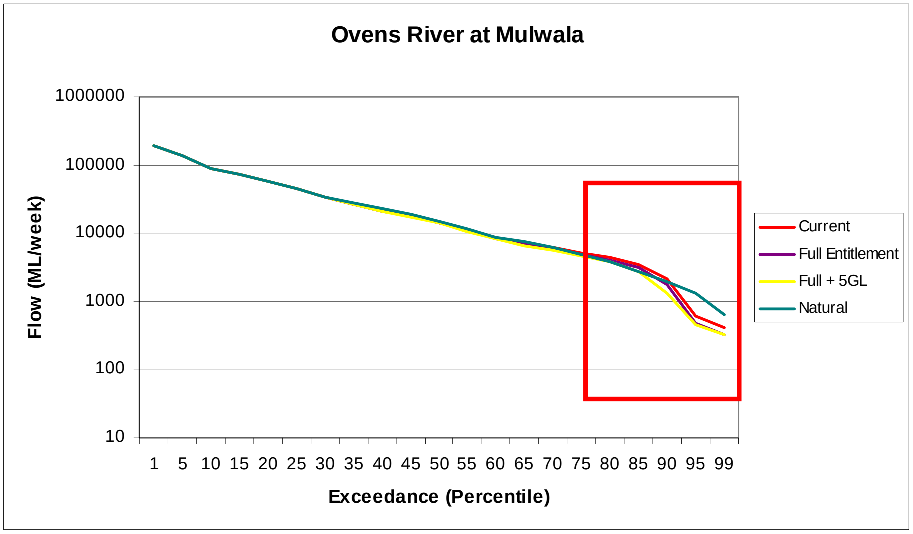


Figure 6: Comparison of modelled natural with current and potential future water demand from Ovens River at Lake Mulwala, 1980-1993. The box on the lots emphasises the period when regulation has the greatest effect on the natural flow regime.

4.5 Potential long-term changes to stream flow

4.5.1 Ovens streamflow management plan

A streamflow management plan (SMP) is currently being prepared for the unregulated areas of the Ovens River catchment above the Buffalo River confluence. The potential impact of implementing the streamflow management plan on the recommendations developed for this study must be reviewed by the Ovens BE Group. For example, it is possible that the Upper Ovens SMP may result in increased environmental flows if required. There may also be some winter fill of offstream storages and this needs to be considered in light of the total volume harvested by Lake Buffalo and Lake William Hovel.

4.5.2 Representativeness of the modeled flow period

Decadal periods of higher and lower flood magnitude and frequency have been identified in SE Australian streams (Brizga et al., 1993; Erskine and Warner, 1988). Robinson (1993) identified three distinct flow regimes in the discharge record of the Ovens River at Bright and Wangaratta. A falling trend in Figure 7 (e.g. 1959 to 1972) represents a drought dominated regime (DDR) in which the annual floods are smaller than the average, and rising trends (e.g. 1950 to 1959) represent flood dominated regimes (FDRs) in annual floods are greater than the average. The period of record used for environmental flow analysis in this study (1980 to 1993) fell within a period defined by Robinson as an FDR. The annual flood series demonstrates that the period 1973 to 1990 was the period of record with the most floods in the period 1946 to 1990. Thus, we can conclude that the Ovens flow record is highly variable from decade to decade, and that the period of record used for the study was characterised by more frequent flooding than normal.

Figure 4.3 Identification of Breakpoints between FDRs and DDRs for the Ovens River at Bright.

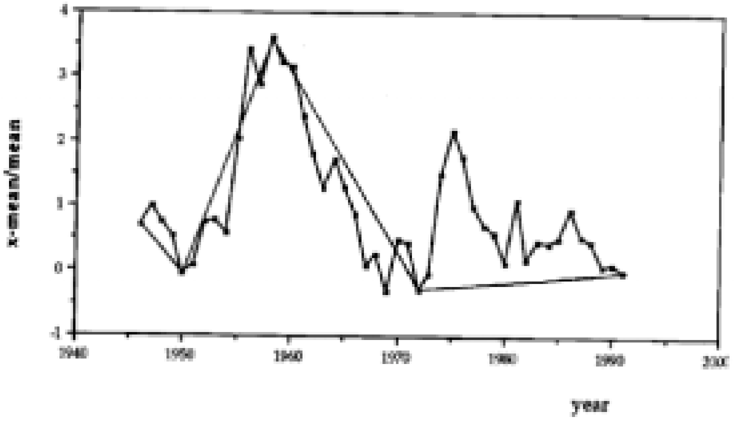


Figure 4.4 Identification of Breakpoints between FDRs and DDRs for the Ovens River at Wangaratta.

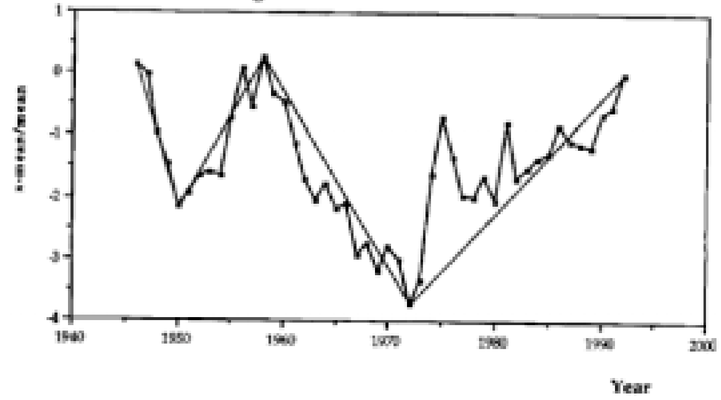


Figure 7: Flow regimes (Flood and Drought Dominated Regimes) of the Ovens river at Bright and Wangaratta. (From Robinson 1993). (*Plot shows the cumulative proportional deviation from the mean for the annual maximum daily flow record*)

4.5.3 Climate and landuse change and streamflow

Long-term changes to climate and landuse in the Ovens catchment may have the potential to affect streamflow in the future. For example, increased temperature due to global warming may result in reduced streamflow in southern areas of the Murray Darling Basin. Modelling undertaken by Bennett (1999) suggested that flows in the rivers of north-east Victoria, including the Ovens River, may decrease by up to 36% over the next 30 years (worst case scenario), and that the frequency of flooding would decrease while the frequency of drought would increase (Tables 4 and 5). While these are the upper limits of changes modelled in the studies reported by Bennett (1999) and modelling predictions about the sustainability of water resources and agriculture should be treated with caution (Henderson-Sellers 1996), they suggest that climate change may significantly alter flows in the Ovens and nearby catchments. Any reduction in rainfall and streamflow may affect the water yield available for irrigation, consumptive and environmental purposes.

Table 4: Scenarios for the year 2030 on the effect of climate change on precipitation and streamflow in snow affected (Mitta Mitta and Kiewa Rivers) and snow free catchments (Goulburn and Ovens Rivers) in Victoria (from Schreider *et al.* (1997) reported in Bennett, 1999)

	Scenario	Precipitation (% change)	Streamflow (% change)
Snow free	Most dry	-7	-36
Snow affected		-6	-30
Snow free	Most wet	+13	0
Snow affected		+13	+9

Table 5: Scenarios for the year 2030 on the effect of climate change on floods and drought in snow affected (Mitta Mitta and Kiewa Rivers) and snow free catchments (Goulburn and Ovens Rivers) in Victoria (from Schreider *et al.* (1997) reported in Bennett, 1999)

	Scenario	August – October floods (% frequency)	January – March drought (% frequency)
Snow free	Most dry	-82	+36
Snow affected		-83	+36
Snow free	Most wet	+41	+5
Snow affected		+62	+1

The Victorian Government intends to invest $8 million in the Replanting Victoria 2020 program (DNRE 1999) as part of its response to Greenhouse effects and other land and water management issues. Much of the new plantation areas are expected to replace what is currently grassland. Given that evapotranspiration rates in plantations are higher than in cleared areas such as grasslands, extensive reforestation has the potential to significantly reduce stream flows from afforested catchments (Vertessy 1999). In a study of 28 sub-catchments of the middle Murrumbidgee River basin, Vertessy and Bessard (1999) reported that the greatest impacts of reforestation might be expected in higher rainfall areas. Average annual runoff declines of up to 500 mm were considered possible with the conversion of grassland to pine plantations, with declines by 100 mm (1.0 ML/ha) possible for 75% of catchment area and 290 mm (2.9 ML/ha) possible for 25% of the Murrumbidgee catchment area that may be afforested.

There is insufficient information available to assess the combined effects of climate and landuse change on stream flow in the Ovens catchment. However, it would be prudent for the farming community and waterway managers to consider the implications of reforestation and global warming on their respective operations. Given the broad scale at which climate and landuse changes may potentially impact on water yield, it is likely that water entitlement negotiations will be required at State, regional and local levels. It is unrealistic to expect that water entitlements will simply be increased to offset any loss of reliability at the expense of maintaining environmental condition or health of streams.

4.6 Groundwater

Given the links between ground and surface waters in the Ovens Basin, groundwater is recognised as a potential source of salt and pesticide contamination (OWQWG 2000, SKM 1997). However, the limited information on groundwater-surface water interactions meant that groundwater was not considered explicitly in this study, and it was assumed that the effects of groundwater recharge or discharge to the river system was picked up in the flow modelling that was undertaken as part of the project.

5 RIVER GEOMORPHOLOGY AND ECOLOGY

This chapter provides an overview of the important geomorphological and ecological features of the study area, and considers the environmental values that should be maintained or protected to ensure that the Ovens River remains a functioning and diverse ecosystem. The environmental threats to the Ovens system are also considered.

5.1 Geomorphic character of the Ovens and its tributaries

The Ovens and King Rivers (with catchments of 3700 km^2 and 1,400 km^2 respectively) drain four major geomorphic zones.

Zone 1: Headwaters zone: Hilly to mountainous terrain on lower Paleozoic sedimentary rocks in the upper catchments. In this zone, the river is steep and dominated by bedrock. This zone is predominantly above the Buffalo and William Hovell dams.

Zone 2: Confined valley zone: Confined floodplains and terraces downstream of the mountain front, extending to Moyhu on the King River, and Markwood on the Ovens River. The active floodplain of the river in this reach varies from 500m to about 3km in width. On the Ovens, this zone includes the influence of the granitic intrusions that form the Mt Buffalo Plateau. These plateaus contribute considerable sand to the Buffalo and Ovens Rivers. This zone of the river is characterised by a gravel bed, with well-defined pool-riffle morphology, and rapid rates of bank erosion and floodplain scouring. The floodplain in this zone, under natural conditions, was characterised by channel avulsions (major jumps of channel position) that would have occurred over periods of decades to centuries.

Zone 3: Upper anabranching reach: Schumm et al. (1996) describe a 'plains region of alluvial fans and high terraces downstream of a line through Moyhu on the King River and Markwood on the Ovens'. The floodplain widens dramatically at these points, and the bed material becomes finer. There is a rapid transition in the main channel of the Ovens River from a gravel bed, pool-riffle stream at Tarrawingee, to a sandy, anabranching stream at the King River confluence. A similar transition is particularly pronounced on the King River where the stream changes abruptly from gravel to a sand bed stream over a few kilometres between Edi Cutting and Moyhu. This important transition marks a decrease in stream and valley slope, and the beginning of an impressive anabranching system of channels.

Under natural conditions both the Ovens and the King Rivers would progressively abandon one channel for another on the floodplain. This process is continuing today. The active channel progressively builds levees until the channel is abandoned for a straighter, lower channel on the floodplain (Schumm 1996). This gradual process probably takes centuries to complete. Tea Garden Creek, for example, is an example of a former main channel of the Ovens, with Deep Creek representing a developing channel. Deep Creek is now larger than the adjacent Ovens River and will eventually capture the main channel (Tilleard 1985). On the King, the same process of abandonment is occurring below Moyhu.

Zone 4: Lower confined reach: Downstream of the Ovens and King River junction the river has entered the Riverine Plains proper. Reedy and One Mile Creeks are major anabranches of the river. Importantly, the floodplain of the river becomes more confined downstream as the river incises into the Shepparton Formation of the Riverine Plains (Bowler 1978). The river below the Reedy Creek Junction is sinuous, with clay banks, and a sandy to fine gravel bed. The channel maintains permanent flow, and frequent flooding. The floodplain is made up of wetlands created by meander cutoffs. In this reach the floodplain is similar to that described on the Goulburn River by Bowler (1978).

5.1.1 History of human impacts on the geomorphology of the Ovens and King Rivers

There have been three major human impacts on the geomorphology of these rivers: gold mining, intensive floodplain cultivation, and river improvement works (Table 6).

Table 6: A brief summary of human impact on the Ovens and King Rivers.

Period	**Impact**
1830s	Valley floors first cleared
1850s	Alluvial gold mining in upper Ovens
1920s – 50s	Upper Ovens floodplain (above Buffalo River confluence) destroyed by dredging above Bright.
1930-40	Streams choked by willows. Impetus to form a River Improvement Trust (formed in 1950 on the King and 1953 on the Ovens)
1950s – 70s	Period of ‘river improvement’ for flood mitigation. Willows removed, channel desnagged (mostly in the upper and middle reaches). Levees were constructed along much of the lower half of the Ovens River. The rivers begin to widen.
1970s – 90s	Period of channel stabilisation. Banks stabilised with rock and river training works. Extraction of gravel from point bars commercially, but also in an attempt to reduce bank erosion. Tobacco growing on the floodplain leads to increased erosion, plus the threat of major channel avulsions across the floodplain.

Gold mining

The following description comes from Beard (1979). The floodplain of the Ovens River was first cleared in the 1830s. Alluvial gold mining began in the 1850s. This was most intense above Porepunkah, but extended down to Myrtleford. The major impact on the river began with the sluicing phase of mining in the 1880s and then with the arrival of bucket dredges in the 1920s. Dredging of the alluvial flats above Porepunkah continued until the mid 1950s. The entire floodplain (2100 ha) was worked in this period, to depths of tens of metres. Floodplains downstream were covered with sludge. The result was that the natural channel of the Ovens River above Porepunkah was destroyed, and the channel downstream was filled with gravel and sludge. Beard (1979) states that the Ovens downstream from Myrtleford has changed from a tight meandering stream to a broad, straight braided stream as a result of mining debris. This artificially wide channel is evident at the junction of the Buffalo and Ovens Rivers.

To put this sediment load into perspective, Ladson (2000) has estimated that by 1913, 35 million m^3 of sediment had been washed into the Ovens River by gold mining. This represents a minimum of 240 years of natural bedload transport.

A slug of finer material (sand and gravel) is continuing down the river. There are reports of pools filling along the river, but it is not clear how far downstream the slug of mining debris has moved.

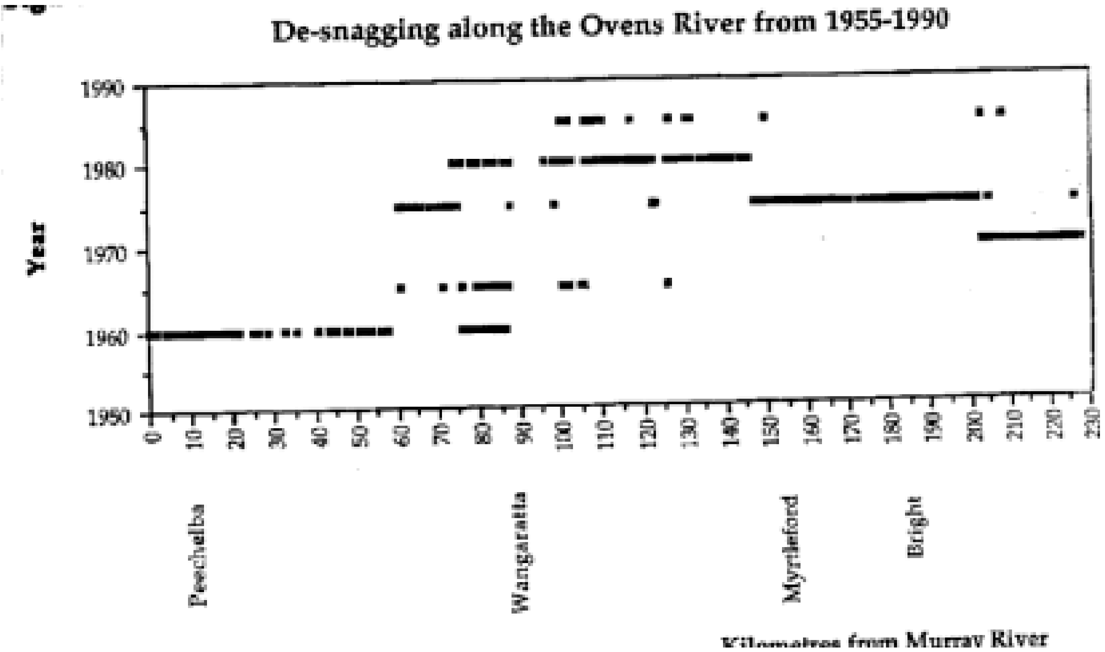
Intensive landuse

The upper floodplains of both the Ovens and King Rivers have been cleared and used for intensive agriculture since the 1830s. However, it was only when tobacco cultivation replaced beef and dairy in the 1950s that the most intensive phase of floodplain use began. Tobacco was planted to the edges of streams, and the friable floodplain was increasingly susceptible to development of flood chutes. The high value of land along these rivers prompted pressure to reduce the damage done by floods and channel erosion. As a result, the King River Improvement Trust was the first river improvement trust (RIT) formed in Victoria (1950), with the formation of the Ovens River Improvement Trust soon after (1953) (Strom, 1962).

Channel 'improvement' works

There has been a long history of flood mitigation and channel stabilisation works on both the Ovens and King Rivers. The Ovens and its tributaries are steep and unstable by the standards of most Victorian streams. The streams have a history of rapid channel migration, particularly following the clearing of riparian vegetation. There is also a history of channel avulsions in the upper reaches, particularly when the floodplains have been cleared for intensive cultivation (especially tobacco). The period over which the process of anabranch development and progressive abandonment takes place increases with distance downstream. Avulsions can occur in a single flood in the headwater reaches, while channels may take hundreds of years to become abandoned in the middle reaches and abandonment may take thousands of years in the lower reaches. Human activities have served to increase the rates of channel change in these streams. The spread of willows into the streams in the 1930s, in particular, reduced channel capacity.

The RITs set about clearing willows, building levees, removing snags, and stabilising the channels. The history of this work is recorded in Robinson (1993). The majority of works were completed between Myrtleford and Wangaratta on the Ovens River, and throughout the length of the King River. In some sections of the river, over half of length of the banks has been stabilised with rock and other structures (Figure 8).



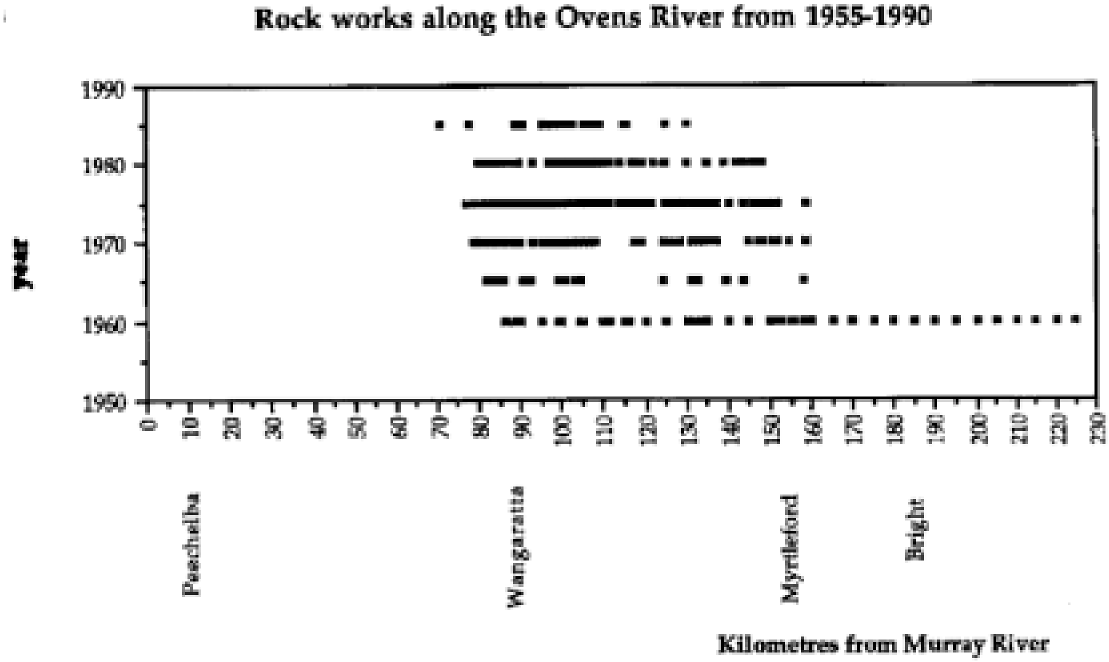


Figure 8: **Distribution of desnagging and rockwork completed on the Ovens River by the Ovens River Improvement Trust between 1955 and 1990 (From Robinson, 1993).**

Another important activity of the Trusts was to encourage gravel extraction from the stream bed from the 1960s to the 1980s. The aim was to improve the flow alignment of the river and reduce bank erosion. It is not clear what the long term effects of this extraction may have been on the river.

Overall, the effect of humans on the present channel of the Ovens and King Rivers has been considerable. Without the intervention of the Trusts, both rivers would have developed new channels during major floods. However, confining the channel within levees will also have exacerbated erosion rates by increasing stream power. Increased sediment load, combined with desnagging and realignment, has led to a much simplified channel in the middle reaches of the rivers.

Thus, the effect of flow regulation on the Ovens River cannot be evaluated without considering the trajectory of other changes occurring in the river. It is important to establish the longer-term changes that are taking place in the rivers, as these influence the longer-term effectiveness of various environmental flow recommendations. The following channel changes could be relevant to future considerations of environmental flow deliberations.

5.1.2 Anthropogenically Induced Sediment loads

The upper reaches of the Ovens River have recovered from dramatic disturbance of the channel in the dredging period of the 1920s. This is testament to the resilience of the stream. However, dredging introduced a huge load of sand and gravel to the reach of stream below Bright. This sediment slug is still making its way through the stream system.

A consequence of the huge sediment load entering the Ovens was dramatic widening and instability in the channel. The result is a wide, featureless gravel bed with little habitat diversity. It may be centuries before this channel has recovered from this damage. The effect of improvements in environmental flows will be moderated by the poor habitat provided by the wide gravel channel in the middle reaches of the Ovens River.

5.1.3 Anabranch development

Both the Ovens and King Rivers naturally switch channels over periods of decades to centuries and channel ‘switching’ (anabranch development) continues on both rivers. Deep Creek on the Ovens River is gradually capturing flow and is now considerably larger than the nearby Brookfield and Pioneer reaches of the Ovens River (Schumm *et al*. 1996). Similarly, Middle Creek, an anabranch of the King River below Moyhu, has gradually captured the river over the last forty years and today carries half of the flow. Such developments will be relevant to environmental flow designs because the flows will be interacting with a changing stream. The proportion of flow carried by various anabranches will change over time.

5.1.4 River management works

River ‘improvement’ works have produced a simplified channel, lacking large woody debris and geomorphic complexity. It is reasonable to conclude that these modifications have had more impact on the health of this stream than has the effects of flow regulation. Limiting the effects of future in-stream works will be as important for the health of the stream as will managing regulated flows.

5.1.5 Likely geomorphic effects of flow regulation

The geomorphic effect of changed flow depends upon the *competence* of the flows involved, for example the amount of sediment they might transport. We can consider the effect in terms of scales of impact. Regulation can influence the magnitude, frequency, and duration of flows that are competent to move different zones of sediment in the channel:

1. High flows (say annual floods and above) are ‘channel forming’ flows. They may influence the size of the channel. These flows control major movements of bed material.
2. Moderate flows (say spring peaks) would influence the shape and composition of bars in the channel.
3. Low flows. These are the flows most influenced by regulation in the Ovens system (see section 4). These flows would have little impact on bed load, or general channel form. They may influence fine sediment infiltration rates.

The effect of regulation on flows in the study area is modest, and regulation is unlikely to alter the processes that affect channel morphology. However, regulation may impact on the amount and timing of inundation of different bed features (habitat). The main effect here would be the width of riffles inundated during summer, with more riffles or riffle areas being wetted or flowing during higher and more constant summer flows. It was not possible to observe the amount of difference in available habitat at the time of inspection due to high flows. The difference in regulated and unregulated flows at the gauges is in the order of tens of centimetres in river height. This amount is likely to be reduced in the wider, uncontrolled riffles. Although there are likely to be some step changes in water levels due to sudden changes in dam operation (e.g. October shut-down of gates on Lake Buffalo), the effect of these changes will be progressively dampened down the river. Regulation is unlikely to affect pool lengths or depths, as pool depth is controlled by the height of the crest of the next riffle downstream. Typically, the proportion of pool habitat increases with distance downstream.

5.1.6 Geomorphic features of the Ovens and King Rivers

The Ovens and King Rivers are of special geomorphic interest. The anabranching reaches of the Ovens and King valleys are excellent examples of active anastomosing channel networks (Schumm *et al*. 1996). In addition, the lower reaches of the river have been little disturbed by desnagging, or other river management works. As a result they are a good example of an intact lowland floodplain system that still experiences a close-to-natural flood regime.

5.2 Water Quality

5.2.1 Physico-chemical water quality

The data used in this section were obtained from the Victorian Water Resources Data Warehouse (www.vicwaterdat.net) and represent observations made from 1979 to the present. Earlier data (1974-1982) are available for the Ovens at Peechelba East from Walker and Hillman (1977) and Brymner (1982). Sampling sites representative of each of the five reaches were chosen and their water quality measurements are summarised in Table 7. Physico-chemical characteristics, particularly their extremes, provide a good guide to the ‘livability’ of the river as an environment.

The data indicate a benign physico-chemical environment throughout the system. There was a general tendency for water quality to decrease with increasing distance down the catchment. The relatively low maximum for suspended solids in the lower Ovens (reach 5) probably indicates the filtering effect of intact floodplain and riparian vegetation in large runoff events. Water quality generally complies with the SEPP (Waters of Victoria) objectives (Government of Victoria 1988). Measures of dissolved oxygen (DO), suspended solids (SS), pH and salinity generally meet water quality objectives, although DO has occasionally fallen below 6 mg/L in reach 5 (minimum concentration = 4 mg/L). A pH minimum below 6 units has been recorded in reaches 2, 4 and 5, and a maximum pH above 9 units has been recorded in reach 5.

Table 7: Summary statistics for water quality parameters for representative sites in each reach. Reach 1 - Buffalo River at Abbeyard, Reach 2 - Ovens River at Rocky Point, Reach 3 - King River at Cheshunt, Reach 4 - King River at Docker Road Bridge, and Reach 5 - Ovens River at Peechelba.

	Mean	**Minimum**	**10%ile**	**Median**	**90%ile**	**Maximum**
Turbidity (NTU)						
Reach						
1	3.3	0.4	1.1	2.1	4.4	78.0
2	5.4	0.5	1.6	3.5	9.0	74.0
3	1.5	0.2	0.6	1.0	2.6	25.0
4	10.8	3.0	4.5	7.9	17.4	81.0
5	14.2	0.8	4.9	11.5	24.9	155.0
Suspended Solids (mg/L)						
Reach						
2	7.9	0.5	2.0	5.0	14.0	170.0
4	17.4	2.0	5.4	12.0	29.2	160.0
5	21.5	2.0	11.0	20.0	33.6	43.0
pH (pH units)						
Reach						
1	7.4	6.4	6.8	7.4	7.9	8.9
2	7.2	5.2	6.5	7.2	7.9	8.2
3	7.3	6.0	6.7	7.3	7.8	8.3
4	6.8	5.8	6.3	6.7	7.3	8.6
5	7.0	5.4	6.4	7.0	7.6	9.2
Salinity - EC @25 (µS/cm)						
Reach						
1	42.4	23.0	30.0	39.0	57.2	99.0
2	43.7	23.0	34.0	42.0	54.8	110.0
3	33.9	19.0	22.0	30.0	49.0	110.0
4	50.1	26.0	35.0	43.0	59.0	450.0
5	82.4	10.0	46.0	70.0	120.0	610.0
Dissolved Oxygen (mg/L)						
Reach						
1	10.4	6.0	8.5	10.6	11.9	13.8
2	9.9	6.7	8.0	10.0	11.6	13.0
3	9.8	7.2	8.1	10.0	11.2	12.6
4	9.1	6.4	7.2	9.0	11.0	12.0
5	8.6	4.0	6.3	8.6	10.6	11.9

In comparison to nearby lowland rivers, the Ovens is more turbid and has higher salinity (measured as electrical conductivity (µS/cm)) than either the Murray or the Kiewa. However, as salinity averages only about 50 ppm salt at the Ovens' discharge to the Murray, there is little sign that salinity is a threat to the river's biota at present. Stream salinity levels may vary over time and space, often with distance from the river's source. Generally the relative ratios of the components that make up the salt load (the major ions) remain constant and can be used to typify a particular stream and catchment. The major ion chemistry of the Ovens differs from that of the nearby Murray and Kiewa Rivers in the degree to which it is dominated by sodium and chloride (Brymner 1982) and suggests a relatively slow rate of geological weathering in the catchment.

Major ion data are available only for the two reaches on the Ovens River (Table 8). Major ion concentration increased downstream, presumably due to inputs from the King River and other tributaries such as Reedy and Fifteen Mile Creeks.

Table 8: Summary statistics for major ions for representative sites in Ovens River at Rocky Point (reach 2) and the Ovens River at Peechelba (reach 5).

Calcium	Mean	Minimum	10%ile	Median	90%ile	Maximum
REACH						
2	1.8	1	1.3	1.6	2.1	11.0
5	2.3	1.3	1.7	2.1	2.9	12.0
Sodium						
REACH						
2	3.7	1.7	2.9	3.5	4.7	8.2
5	8.8	3.1	4.5	7.4	14.0	31.0
Potassium						
REACH						
2	0.7	0.25	0.5	0.7	0.9	2.2
5	1.2	0.25	0.8	1.1	1.7	6.6
Magnesium						
REACH						
2	1.7	0.8	1.3	1.7	2.2	2.3
5	2.3	1.2	1.6	2.1	3.2	5.2
Chloride						
REACH						
2	2.7	1.0	2.0	3.0	3.4	6.0
5	9.9	1.0	4.0	7.0	15.0	89.0
Sulphate						
REACH						
2	1.2	0.4	0.5	1.0	2.0	4.9
5	2.9	0.3	1.3	2.3	5.4	12.0

Cold water releases from large dams may affect the distribution or biology of downstream biota. A preliminary assessment, based on the comparison of stream temperature below Lake Buffalo and Lake William Hovell with nearby (unregulated) streams at similar elevations, suggests that there may be cold water releases from Lake Buffalo (cf the Buckland River) in some years (Appendix 3). Water temperature in the King River was consistently above that of the Ovens River at Harrietville. However, the distance between the two locations makes it difficult to draw conclusions on whether or not cold water releases are an issue in the King River. The potential for cold water releases from the two dams is currently being investigated by DNRE. For example, the extent of cold water releases can be measured by modelling stratification of the dams and the recovery of water temperature downstream, or by direct measurements of stream temperature above and below the dams in summer-autumn.

A number of reports (e.g. EPA 2000, OBWQWG 2000, Tiller 1991 and 1993) identify that the concentrations of plant nutrients nitrogen and phosphorus are a cause for concern in the Ovens catchment. Major nutrient sources include diffuse runoff from dryland and irrigated agriculture land, stream erosion, urban stormwater runoff and point sources such as sewage treatment plants and trade waste plants (OBWQWG 2000).

Long-term nutrient data were only available for the Ovens River at Rocky Point, the King River below Edi and the lower Ovens River (reaches 2, 4 and 5) (Table 9). Based on median values, reaches 2 and 4 (mid Ovens and lower King Rivers) had similar TN (TKN + NOx) and TP concentrations, with both TN and TP concentration highest in the lower Ovens River (reach 5), presumably due to urban and agricultural runoff, and sewage and industrial discharge. The low level of "readily available" N and P relative to total concentrations (21 – 32%) suggests that much of the nutrients are bound up in organic and particulate material. Although there may be periods when nutrient levels exceed the recommended maxima (EPA 1995), in general nutrient levels represent a minimal ecological risk as long as the river's functional biodiversity is maintained (although this assumption should be confirmed scientifically).

Overall, the available data indicate that water quality conditions across the Ovens are generally good (although with some nutrient enrichment) and should support a viable and diverse ecosystem under the right conditions of catchment land and flow management. It was not possible to detect any impact on water quality due to changes to the flow regime associated with current levels of regulation and diversion of water.

5.2.2 Other Water Quality Factors

Groundwater

An important gap in our understanding of water quality is the role of groundwater. The relationship of the river system with groundwater is one area likely to change with either flow management or catchment land-use changes. However, there is insufficient information available to predict effects.

Pesticides

Early studies (Walker and Hillman 1977) made a limited number of measurements of pesticides and found detectable quantities of DDT and Dieldrin in sediments and in water during high flows in the lower Ovens River. As the use of these pesticides had ceased by this time, it was assumed that the traces were associated with soil deposits that had been mobilised from the upstream floodplain. Subsequent work conducted by the EPA (McKenzie Smith *et al*. 1994) also found detectable quantities of organochlorine pesticides in stream sediments across the study area and concluded that DDD, DDE, DDT and dieldrin residues were most likely transported from surrounding land and upstream sources. Moore *et al*. (1996) found that while pesticide residues were detectable in stream sediments across the Ovens catchment, their impact on macroinvertebrates (if any) could not be separated from other anthropogenic effects. Moore *et al*. (1996) also suggested that there was little evidence of sub-lethal affects on fish, although the sample pool of fish used for this analysis was small.

In view of the relatively healthy fish communities reported for the lower Ovens and healthy macroinvertebrate communities in other reaches, foodweb concentration of pesticides may not be a problem. However this may bear further examination, particularly in the light of a shortfall from expected macroinvertebrate families in the lower Ovens River and the limited amount of pesticide residue analysis for fish.

Table 9: Summary statistics for water quality parameters for representative sites in each reach. Ovens River at Rocky Point (reach 2), King River at Docker Road Bridge (reach 4) and Ovens River at Peechelba (reach 5).

	Mean	Minimum	10%ile	Median	90%ile	Maximum
TKN (mg/L)						
REACH						
2	0.190	0.050	0.090	0.170	0.300	1.300
4	0.210	0.050	0.100	0.200	0.300	0.820
5	0.320	0.050	0.200	0.300	0.500	1.200
Total P (mg/L)						
REACH						
2	0.030	0.002	0.012	0.018	0.037	0.530
4	0.030	0.012	0.016	0.026	0.051	0.190
5	0.060	0.011	0.034	0.049	0.087	0.520
NOx (mg/L)						
REACH						
2	0.090	0.002	0.0298	0.078	0.190	0.300
4	0.110	0.002	0.0163	0.055	0.254	0.550
5	0.150	0.002	0.0388	0.140	0.280	1.000
FRP (mg/L)						
REACH						
2	0.010	0.002	0.002	0.004	0.012	0.043
4	0.000	0.002	0.002	0.003	0.006	0.015
5	0.010	0.002	0.003	0.010	0.028	0.230
Silica (mg/L)						
REACH						
2	8.59	5.30	6.31	8.70	10.00	11.00
5	8.70	0.40	6.47	9.00	11.00	12.00

5.2.3 Effect of river regulation on water quality

Preliminary investigations indicate cold water releases from Lake Buffalo in some years. Apart from potential cold water releases, water quality remains largely unaffected by flow regulation but has been affected by inputs of nutrients and organic pollution, presumably in runoff form agricultural and urban areas.

5.3 Macroinvertebrates

Water quality monitoring generally involves the measurement of physical and chemical aspects of the water, such as pH, salinity, turbidity, nutrient levels and toxicants. As this type of water quality data provide a ‘snapshot’ of environmental conditions at the moment samples are taken, they may fail to detect occasional changes or intermittent pulses of pollution. To overcome this, many biological monitoring programs involve the sampling of aquatic animals such as macroinvertebrates. Because they live at the site for some time, macroinvertebrates present at a site ‘integrate’ the impacts of environmental change in a river ecosystem (e.g. pollution effects over time). For example, the presence or absence of particular species provides information about water quality; some species are known to have particular tolerances to environmental factors such as temperature or levels of dissolved oxygen. Other information can be obtained from the number of species found at a site (biological diversity), the number of animals found at a site (abundance) and the relationship between all animals present (community structure).

The biota are also responsive to changes in habitat (i.e. communities will be different in stony riffles compared with sand or clay bottomed pools; the presence of aquatic plants affects faunal diversity etc.). As stream flows are an important feature of the stream habitat, macroinvertebrate communities can also be markedly different under different flow regimes.

The Monitoring River Health Initiative was introduced as part of the National River Health Program and is a biological assessment scheme for evaluating river health. Data on macroinvertebrates and environmental variables from about 200 reference sites from across Australia (sites that are relatively unimpacted or otherwise desirable) have been used to build models that are called AUSRIVAS. The AUSRIVAS models predict the macroinvertebrates that should be present in specific stream habitats under reference conditions. It does this by comparing a test site with a group of reference sites, which are as free as possible of environmental impacts but have similar physical and chemical characteristics to those found at the test site.

The Victorian EPA has sampled over 600 sites across Victoria as part of the First National Assessment of River Health; of the 40 sites sampled across the Ovens River Basin, 9 were located within the study area (EPA 2000). Assessment of stream condition at these 9 sites across the study area has been based on:

- The number of macroinvertebrate families recorded (a measure of biodiversity);
- SIGNAL scores (a measure of organic pollution);
- Statistical patterns in macroinvertebrate and environmental data (classification and ordination);
- AUSRIVAS scores (a measure of river health - based on the ratio of observed versus expected number of families generated using AUSRIVAS models).

Use of a number of indicators to assess ecosystem health is desirable, improving the robustness and reliability of the conclusion. When they are in accord, greater confidence may be placed on the outcome, and when there is a discrepancy, this can be used to indicate the type of environmental problem involved.

Analysis using classification and ordination techniques showed three main groupings of streams in the Ovens catchment (EPA 2000) – high altitude streams, intermediate or foothill streams, and lowland streams. All the sites within the study area were included in the intermediate or foothills stream group, or in the lowland stream group (Table 10). The intermediate group consists of streams in the foothills and higher valleys of the Ovens and King Rivers. These streams vary from smaller tributaries with rocky substrate and moderate flow, to broad sections of the Ovens and King Rivers. The lowland sites are characteristically large, slower flowing rivers but also include smaller streams. Most sites in this group are on the Ovens River downstream of Wangaratta or on the adjacent floodplains.

Intermediate group

The streams in this group are mostly in the Ovens and King valleys and pass through forests, agricultural land, pine plantations and some small towns. They vary considerably in substrate, current, shading, and frequency of riffles and water temperature. The dominant macroinvertebrates in this group consists of mayflies and caddisflies, with beetles (Coleoptera), water bugs (Hemiptera) and dragonfly larvae (Odonata) becoming more common and the majority of sites had diverse macroinvertebrate assemblages.

AUSRIVAS rated most of these sites as being in good condition (equal to reference sites) or above reference (the latter usually indicative of mild nutrient enrichment) (Table 10).

Lowland group
These rivers are surrounded by dryland grazing, viticulture, broadacre cropping and some irrigated horticulture. The rivers are typically slow-flowing streams with predominantly sand or clay bottoms and higher turbidity than streams higher up the Ovens catchment. Riffles are rarely found in the lower streams. The dominant macroinvertebrates in this group consist of water bugs, beetles, midge larvae (Chironomidae), dragonfly larvae and some mayflies.

Sites in this group were in the vicinity of and downstream of Wangaratta. Turbidity, salinity, nutrient levels and water temperature were all higher at these sites than at sites higher in the catchment. AUSRIVAS scores showed all but one of the sites to be below or well below reference condition. Fewer than expected families were present (Table 10) and SIGNAL scores indicated mild pollution.

Summary
The health of streams (as indicated by macroinvertebrate communities) in the Ovens catchment declines from the upland forested sites to lowland riverine areas, but overall the health of streams in the catchment is reasonably good compared with many other catchments in Victoria. Generally, river health decreases with increasing distance downstream, reflecting the accumulation of impacts, higher populations and more intensive land use at lower altitudes.

SIGNAL scores suggest that water quality suffered from mild pollution at a number of sites across the study area, particularly near Wangaratta. AUSRIVAS results suggest that instream habitat for macroinvertebrates is in reasonable condition across much of the upper and middle catchment. The broad riffles found in this area, slightly raised nutrient levels and the generally good flows in the streams support a diverse and abundant macroinvertebrate fauna.

The results for sites in lowland areas indicated that there were fewer macroinvertebrate families than expected. The results for the Ovens River at Peechelba were surprising, as the river in this area appeared to have excellent habitat features. Possible reasons for the less than expected number of families include (i) the poorer water quality recorded in this reach, which had relatively high nutrient concentrations and turbidity, or the way in which AUSRIVAS models are constructed. The standardised approach of AUSRIVAS, which samples riffles and edge habitat, does not sample potentially important habitat such as snags in the river. AUSRIVAS models also rely on the characterisation of reference condition, which is often difficult for lowland rivers. The combined effect of missing important habitat and the difficulty of characterising reference conditions for lowland rivers means that the lower than expected number of families may simply be a result of imprecision of the AUSRIVAS models.

5.3.1 Impact of river regulation on macroinvertebrates

The current level of river regulation does not appear to have adversely affected macroinvertebrates, especially in the upper reaches of the study area. The less than expected macroinvertebrate families in the lower Ovens River reach may be due to multiple stressors and it is not possible to separate the effects of regulation, if any.

Rapid short-term changes in flow and water depth has the potential to harm macroinvertebrate populations, for example by stranding invertebrates that inhabit riffles and other shallow areas of the stream. This may potentially be an issue below Lake William Hovell during hydroelectricity production and in the lower areas of the Buffalo and King Rivers if weekend pumping significantly reduces flow in the rivers.

Table 10: AUSRIVAS and SIGNAL scores for combined season edge samples from sites in the Ovens catchment. **Within each group sites are arranged alphabetically. Family numbers fewer than 25 are highlighted, as are values of total Phosphorus and total Nitrogen which exceed nutrient guideline maxima.**

site code	Site name and location	AUSRIVAS	SIGNAL	No. of Families	Total N (mg/L)	Total P (mg/L)
	Intermediate altitude sites					
CAA	Buffalo R, Merriang Rd near Myrtleford	1.24	5.81	39	0.245	0.009
CAC	Ovens R, d/s Myrtleford	1.15	6.00	35	0.105	0.006
CCJ	King R @ Oxley	0.88	5.73	27	0.204	0.016
CCL	King R @ Edi Cutting	0.94	5.53	31	0.259	0.009
CCP	Ovens R @ Braithwaite Pumping Station	1.03	6.18	29	0.114	0.007
CCU	Ovens R @ Mills View	1.12	6.23	36	0.100	0.012
CCV	Ovens R @ Tarrawingee Bridge	0.81	5.68	23	0.157	0.009
	Lowland sites					
CBV	Ovens R, Robinson Rd	0.49	5.44	17	0.265	0.030
CCI	Ovens R @ Ovens Tk	0.49	5.24	19	0.321	0.030
CBB	Ovens River @ Peechelba	0.66	5.29	19	0.357	0.036
		AUSRIVAS	**SIGNAL**			
	Above Reference	🟦	🟦	**Excellent**		
	Reference	🟩	🟩	**Good**		
	Below Reference	🟨	🟨	**Fair**		
	Well below reference	⬛	⬛	**Poor**		
	Impoverished	🟥	🟥	**Very poor**		

5.4 Aquatic and Riparian Vegetation

The riparian and aquatic vegetation of the Ovens River has not been much studied and very little information has been published. Despite this, the Ovens River lowlands have developed a reputation within ecological research circles as a rare example of an unregulated lowland river. Consequently, the area has attracted a range of research projects, some of which have included site and vegetation descriptions

5.4.1 Riparian Vegetation

The composition of riparian vegetation changes from upland to lowland as plant species respond to longitudinal changes in climate, flow characteristics (notably stream power and flood duration) and to substrate. Longitudinal variation in species composition along the Ovens can be inferred from a series of vegetation profiles, covering river channel to hillslope and showing the distribution of tree and shrub species (Stelling 1994); these have been prepared based on historical information, as a guide to restoration plantings (J. Sloan, pers. comm.). Using Stelling's (1994) work as a guide to the riparian zone shows that the species richness of riparian shrubs and trees is much higher in moist upland reaches and decreases steadily downstream. Stream bank species such as *Acacia melanoxylon*, *Bursaria spinosa* and *Hymenanthera dentata* are restricted to the upper river corridors, whereas *Acacia dealbata* and *Callistemon sieberi* occur over a wider range and are also found lining the channels and main anabranches on the floodplains downstream of Wangaratta.

Riparian vegetation, because of its close association with water and rivers, is subject to a multitude of anthropogenic influences, some being the type of land use, such as clearing, mining, grazing, and some being the well-intentioned management responses such as de-snagging and river improvement works, as outlined in Section 5.1.1. The original lowland riparian vegetation has been given as (Department of Agriculture 1970):

"*On the floodplains and along the banks of rivers and streams, river red gum (Eucalyptus camaldulensis) was and still is the characteristics tree of the lower portion of the area. Originally it formed a forest or dense woodland near Wangaratta, coarse tussock grasses being the main understorey, with dense scrub confined to the actual banks of streams, and including Ovens wattle (Acacia pravissima), black wattle (Acacia mearnsii), burgan (Leptospermum phylicoides) and swamp bottle brush (Callistemon paludosis), which have persisted up to the present time. Burgan was more prevalent upstream from Wangaratta and dogwood (Cassinia aculeata) was present on the stream banks at Myrtleford and further upstream.*" (Note: names cited as in Department of Agriculture 1970, recent name changes have not been updated in the text above).

The river red gum riparian woodland downstream of Wangaratta, although modified and containing some exotic species, still retains the character suggested by the Department of Agriculture (1970). However, the riparian fringe between the two dams and Wangaratta has been exposed to a series of impacts, such as 'river improvements', clearing and grazing, and in most parts its character has been substantially changed by the presence of exotic species.

Field observations suggest that through the middle of the catchment, the contemporary ground cover is frequently dominated by exotic species, most notably by blackberry (*Rubus fruticosus)* in the moister, cooler upland reaches. Upstream of Wangaratta, the understorey is rich in introduced agricultural and pasture weed species, typically in the families Poaceae, Asteraceae and Brassicaceae. In contrast, the riparian fringe downstream of Wangaratta is rich in perennial native grass and herb communities, and with few exotic species around billabongs in the river red gum forest-woodland (CRC for Freshwater Ecology, unpublished data).

5.4.2 In-channel macrophytes.

Knowledge of the distribution ecology and flow responses of in-channel macrophytes for upland and lowland inland rivers is sparse across the Murray-Darling Basin. It can be expected that species richness and abundance, and the range of life forms found will be constrained by the availability of suitable habitats within the channel; in turn this will be defined by channel forms, type of substrate, water velocity and whether the canopy of the riparian zone closes over the channel. Geomorphic changes (see Section 5.1.1) will have had an effect on habitat for macrophytes; a wide featureless gravel bed river does not offer the types of microhabitats suitable for macrophytes. Similarly, a mobile sediment slug can be an unstable substrate and abrasive growing conditions.

The EPA Victoria records in-channel macrophyte presence and relative abundance as habitat variables for its routine macroinvertebrate sampling program; plant identification is to genus level. Records for 1997-1999 for the study area were complied (N. Bates, Vic EPA, pers. com.). These show that abundance of in-channel macrophytes (recorded as relative cover) is generally low (<10% of channel edge) and that structural diversity is low, with emergent macrophytes being the most common growth-form. Emergent macrophytes include records of *Bolboschoenus*, *Carex*, *Cyperus*, *Eleocharis* ?*sphacelata*, *Juncus*, *Phragmites*, *Scirpus*, *Triglochin* and *Typha*. Note that these are incidental data, rather than the results of a survey designed and targeting in-channel macrophytes. Nonetheless, the findings are consistent with observations made during the field inspection. In general, the lack of any records for emerging herbs, free-floating and submerged species, suggests that these growth-forms are very uncommon in the main river channels of the Ovens system.

The distribution of the common reed *Phragmites* may have contracted in historical times. The EPA data suggests the most common macrophyte in the rivers is *Cyperus*, whereas the historical perspective of Stelling (1994) shows *Phragmites australis* as the characteristic species in the stream bed throughout most of the Ovens River valley. This evidence, though slight, is consistent with changes in *Phragmites* distribution on other lowland rivers in the Murray-Darling Basin (Roberts 2000).

5.4.3 Macrophytes in billabongs

Temporal patterns in macrophyte presence and abundance have been recorded in two separate unpublished studies on the red gum dominated floodplain downstream of Wangaratta. Both studies show that, like other lowland wetlands in the Murray-Darling Basin, macrophyte species richness is low. Brooks (1997) working on crayfish habitat recorded 14 taxa from 8 billabongs. However, structural diversity (i.e. the range of growth forms found) was greater than for in-channel macrophytes, with 6 growth forms. The most common growth-form in the billabongs was emergent macrophytes, while the least common forms were submerged and free-floating macrophytes.

Species composition of these lowland wetlands varies through the year and in response to water regime. Billabongs with alternate wet and dry phases develop characteristic species assemblages during the dry, wet and flood recession phases. The plant communities that develop during the wet phase are typically dominated by *Potamogeton tricarinatus, Myriophyllum papillosum*, *Triglochin procera* / *Triglochin multifructosum* and *Pseudoraphis spinescens* (Brooks 1997, CRC for Freshwater Ecology, unpublished data). Communities dominated by these robust perennials are typical of lowland billabongs and are found on the Goulburn, Murray and Murrumbidgee floodplains. Such billabongs typically receive frequent winter-spring flooding, for example every 1-2 years for several months.

The plant communities that develop during the recession phase are quite distinctive and tend to be similar between billabongs (CRC for freshwater Ecology, unpublished data). Flood recession is an opportunity for fast-growing herbs and forbs with low competitive ability and short life-spans, so is typically a mixture of ruderal, amphibious and opportunistic species. Conditions during flood recession are also suitable for moisture-loving terrestrial exotics, so billabongs may become dominated by floodplain exotics. Experience from elsewhere in the Murray Darling Basin suggests that this type of community, dominated by exotic annuals, becomes dominant if flood frequency is reduced.

5.4.4 Weeds.

Riparian weeds have a long history in the Ovens river Valley. Blackberry (*Rubus fruticosus)* was one of the first weed species to become established, occupying stream courses, billabongs and parts of the floodplain (Department of Agriculture 1970). Blackberry, willows (*Salix*), notably *Salix cinerea* and *Salix X rubens*, and hawthorn (*Cretageus monogyna*) are now recognised as seriously invasive environmental weeds in the riparian zone in Victoria (Carr *et* *al.* 1992). Exotics such as willows that can sprout from broken fragments and be dispersed downstream by flowing water are especially threatening to biodiversity and ecosystem processes.

The ground stratum in the riparian forests and woodlands has not been systematically described but, by analogy with other riverine systems in the Murray-Darling Basin, it is here that most of the introduced species are expected to occur. Studies of other regulated river floodplains suggest that as many as 20-30% of herbs and forbs species are likely to be introduced, with many being pasture and crop weeds, or pasture species from predominantly terrestrial plant families such as Poaceae, Asteraceae, Fabaceae, Brassicaceae, Lamiaceae, Rosaceae and Scrophulariaceae. These occur on the floodplain because of the moist and more fertile conditions, particularly where perennial cover has been reduced through grazing or other environmental change.

In contrast to the floodplain understorey, the number of introduced macrophytes in wetlands is generally much fewer, and typically quite different families are represented. Two introduced aquatics on the Ovens, umbrella sedge *Cyperus eragrostis* which grows at the water line through summer, and starwort (*Callitriche stagnalis*), are now so common in the Murray-Darling Basin that few realise these are introduced. One aquatic weed, *Ludwigia palustris*, apparently originated in the Ovens and Kiewa river systems (Aston 1967); first noticed in 1964, it is now spreading slowly downstream and into the Murray but appears not to be dominant.

5.4.5 Aquatic vegetation of the Ovens River in a broader context.

The information available on macrophytes is sparse but there are indications that, taking a broader perspective, there are areas of special significance, such as the lowland billabongs and the in-channel habitat. The condition of the herb-dominated wet-dry billabongs in the red gum woodlands contrasts with the condition of the billabongs in semi-cleared agricultural areas upstream of Wangaratta: here the fringe of trees and shrubs is lacking or greatly reduced, and the emergent plant communities are frequently characterised by *Juncus* spp, an emergent species resistant to trampling and grazing, unlike the aquatic herbs. As for the in-channel macrophytes, although their abundance was low, the results of a statewide analysis of macro-invertebrate communities (Marchant *et al.* 1999) suggests that Ovens River sites were amongst the highest in the state in terms of species richness and edge cover of macrophytes.

5.4.6 Impact of river regulation on aquatic vegetation

Plant species vary in the extent to which they are season specific or season generalist. Unfortunately the seasonal response for many Australian species is not well known (see Roberts and Marston 2000) and we lack the data to describe the seasonal response for relevant species in the Ovens catchment, notably the regeneration requirements of riparian shrubs such as Callistemon.

The seasonal shift in the flow regime of the Ovens system (e.g. a slight delay of floods due to filling of the dams; isolation of the river from its floodplain due to levees; higher than normal low flows in summer-autumn in some reaches) may affect species composition, although the effects are likely to be subtle. Changes to vegetation community structure due to regulation, if any, are most likely to occur for herbs on the river banks and for wetland vegetation, especially in lowland areas. However, until more is known about which plant species might be responding (or used to respond) it is not possible to quantify possible shifts in vegetation structure. For example, the supplementary flows released to supply water for the Murray River in March may flush the river banks and encourage germination, or irrigate species that geminated a few weeks previously. This could be good or bad, depending on the species affected (native or exotic). It could also mean that habitats such as gravel bars are colonised at a faster rate than might be expected or that introduced moisture-loving plants (i.e. not well-adapted to wet-dry regimes) could be encouraged to persist. However, the effects are likely to be subtle and hard to anticipate based on our current knowledge. A survey of in-channel macrophytes by macrophyte specialists is required to identify the aquatic and riparian vegetation present and to set workable baselines and benchmarks for assessing changes to vegetation communities due to variations in flow regime.

Based on limited information and field observations, it is likely that the history of disturbance to the rivers and current land management practices (e.g. livestock access to waterways and wetlands; presence of levees) are likely to have had a greater influence on vegetation communities than the flow regime.

5.5 Fish Populations in the Ovens and its tributaries

The status of fish populations is a key parameter by which the general public gauges river health, and will be a key criterion by which the effectiveness of environmental management of the Ovens River will be assessed in the future. Insights into the state of fish communities can be gained from:

- The number of species;
- The number of threatened species;
- The number of species expected to occur but are missing;
- Species abundance;
- The structure of populations; and
- The number of alien species present.

Angling is Australia’s largest participator sport and one that provides many recreation and tourism opportunities in rural areas. Despite their overall decline (Harris and Gehrke 1997), there is considerable interest in angling for native species such as Murray cod, and there is enormous support for native fish species in the Ovens River. Thus, fish fauna contributes substantially to the biodiversity, rural tourism and culture of the Ovens River catchment.

5.5.1 Previous investigations

A Native Fish Management Strategy has just been completed for the Murray Darling Basin (Koehn and Nicol 1999) that outlines remedial actions to address threats to native freshwater fish. Assessments and recommendations for maintaining native fish populations in the Ovens River made in this study were developed within the context of this overarching Native Fish Management Strategy.

The Ovens River has been a major site for “the cod radiotracking project’ (Koehn 1997, Koehn and Nicol 1998, Koehn 1997), which investigated the movement and habitat requirements of the Murray cod. Fish populations in the main river channel and associated billabongs were sampled during this study. This study found Murray cod to be widespread throughout the river, utilising the abundant large woody debris as preferred habitat. Murray cod moved widely throughout the river system, including through anabranch channels when they became flooded, as part of post-spawning migrations. Murray cod from Lake Mulwala and the lower reaches of the Ovens River have been shown to move upstream as far as Myrtleford, then return to their original 'home' areas following spawning.

Sanger (1984, 1986) conducted taxonomic studies on blackfish from which a new species, the two-spined blackfish (*Gadopsis bispinosus*) was differentiated from the river blackfish (*Gadopsis marmoratus*). Koehn (1986) reported a 10-fold increase in two-spined blackfish populations in the Ovens River at Porepunkah, following habitat improvement by the addition of habitat in the form of boulders.

The Ovens River (Peechelba area) has recently or is currently being used as a site to study:

- Habitat use by larval fish (A. King, CRCFE);
- Billabong fish communities in relation to water quality (D. McNeil, CRCFE);
- Habitat and competition between gudgeons (R. Stoffels, LaTrobe University);
- Ecology of the yabby (J. Brooks, Monash University);
- Spatial and temporal scales project (T. Hillman, CRCFE); and
- Lowland river production (B. Gawne, CRCFE).

The value of the lower Ovens River as a scientific reference site cannot be overstated.

5.5.2 Fish of the Ovens river

The Ovens River is one of the few remaining unregulated rivers of the Murray-Darling Basin. Its lower reaches contain a relatively intact riverine floodplain with a largely natural flood regime and a representative fish fauna. The fish fauna of the Murray-Darling Basin is relatively depauperate by world standards. Only 33 native species are present, several of which are restricted to the lower, estuarine reaches in South Australia. This is far fewer than other large rivers such as those in the Amazon Basin, where more than 1300 species have been recorded (Cadwallader and Lawrence 1990). The uniqueness of the fish fauna of the Murray Darling Basin makes it an important component of Victoria's biodiversity; many of the 33 native species are found in the Ovens River (15 species), along with 8 introduced species (Table 11, Appendix 3). Native species range in size from the Murray cod, which is Australia's largest freshwater fish (recorded up to 113 kg), to smaller species such as Australian smelt that weigh only a few grams. The Ovens River supports one of the best remaining populations of Murray cod in Victoria.

There are concerns about the conservation status of ten of the native fish species recorded in the Ovens River, with five species considered to be nationally threatened or rare (Table 11). This includes the Trout cod, which is now considered to be critically endangered (National Trout Cod Recovery Team, unpublished data). The natural range of this species is now restricted to about 120 km of the Murray River immediately downstream of Lake Mulwala, and is now totally protected. Trout cod is currently being stocked into a section of the Ovens River downstream of Wangaratta with the hope of re-establishing a population.

The introduced Brown trout, Rainbow trout, Carp, Goldfish and Redfin are widespread and occur in all the study reaches. Carp and Gambusia are listed as noxious in Victoria. Gambusia may be expected to be more widespread than current records indicate due to their small size and use of shallow wetland habitats, which have not been comprehensively surveyed. Oriental weather loach has spread rapidly downstream of Wangaratta to the junction with the Murray

River. Brown and Rainbow trout are prolific in the mid and upper reaches of the Ovens catchment and have been widely stocked.

Carp have gained much attention in recent years and are often blamed for the ills of river systems in the Murray Darling Basin. However, it is not yet clear whether Carp are a symptom rather than a major cause of the decline of river systems. The biology of Carp and approaches for control using vertebrate pest management principals have been outlined in Koehn *et al*. (2000). Other methods for control are discussed in Roberts and Tilzey (1998) and a National Carp Management Strategy has been launched. Carp have the typical attributes of a successful invasive species: high environmental tolerance levels, low habitat specificity, high fecundity and high levels of mobility.

Table 11: Status of freshwater fish species found in the Ovens River (Victorian conservation status from Department of Natural Resources and Environment 1999; National conservation status form Australian Society for Fish Biology). CE= critically endangered, E= endangered, V=vulnerable, PT=Potentially threatened, DD=Data deficient, FFG=listed under the Flora and Fauna Guarantee Act, A = Abundant, C=common in the Ovens catchment, S=stocked T=translocated N=Noxious, Aqu=Aquarium species, R=Rare.

Common Name	Scientific name	Conservation Status in Victoria	Conservation Status Nationally	Other Status
Native species				
River Blackfish	*Gadopsis marmoratus*			A, C
Two-spined Blackfish	*Gadopsis bispinosus*			C
Flat-headed Galaxias	*Galaxias rostratus*	DD	V	
Mountain Galaxias*	*Galaxias olidus*	DD		
Murray Cod	*Maccullochella peelii peelii*	V, FFG		A, C
Trout Cod	*Maccullochella macquariensis*	CE, FFG	E	S
Golden Perch	*Macquaria ambigua*	V		A, S
Macquarie Perch	*Macquaria australasica*	E, FFG	V	A, T
Silver perch	*Bidyanus bidyanus*	CE, FFG	V	A
Southern Pygmy Perch	*Nannoperca australis*			
Australian Smelt	*Retropinna semoni*			
Freshwater catfish	*Tandanus tandanus*	V, FFG	PT	A
Western carp gudgeon**	*Hypseleotris klunzingeri*			C
Crimson spotted Rainbowfish	*Melanotaenia fluviatilis fluviatilis*	DD, FFG		
Unspecked hardyhead	*Craterocephalus stercusmuscarum fulvus*	FFG		
Introduced species				
Brown Trout	*Salmo trutta*			A, S
Rainbow Trout	*Oncorhynchus mykiss*			A, S
Carp	*Cyprinus carpio*			N
Tench	*Tinca tinca*			R
Goldfish	*Carassius auratas*			Aqu
Redfin, (English perch)	*Perca fluviatilis*			A
Gambusia	*Gambusia holbrooki*			N
Oriental weather loach	*Misgurnus anguillicaudatus*			Aqu

* A north eastern Victorian form has been listed as data deficient (Department of Natural Resources and Environment 1999)

**A species complex

Chinook salmon (*Oncorhynchus tshawytscha*) have also been recorded in the upper reaches of the Ovens River and are thought to be escapees from a fish farm at Germantown (Baxter 1986). The river and two-spined blackfishes form a lowland/upland species pair with the overlaps in their distribution occurring in reaches 2 and 3. The mountain galaxias is absent from records from the Buffalo river where it would be expected and where it has been recorded from the stream above Lake Buffalo. This species is often absent from areas where it is subjected to predation by trout and this may be the case in the reaches of this study. Freshwater catfish would have been expected to inhabit reach 4 and Gambusia may be more widespread than records indicate. Fish data are most complete for reach 4, which has been the subject of intensive research efforts over the past decade.

5.5.3 Connectivity of the Ovens River

The importance of fish movement across the river system throughout the year, as well as movement into anabranches, floodplain channels and onto the floodplain itself, is now understood (Mallen-Cooper *et al.* 1996, Koehn and Nicol 1998, Koehn 2000). Such movements are essential to complete lifecycles, access new habitats and food resources, and to recolonise habitat areas. Barriers to fish movement may be small (regulators, levees, road crossings) or large structures (large dams, weirs, locks). Longitudinal continuity is also an issue, as providing passage past one blockage is only successful up to the next barrier. Barriers to movement can apply upstream, and downstream and onto and off the floodplain. There are no large barriers to fish movement in the Ovens River; Lake Buffalo and Lake William Hovell are major barriers on the Buffalo and King Rivers. The weir controlling diversion to Tea Garden Creek serves as a barrier to fish migration from the Ovens River and, along with levee banks, also disconnects the nearby floodplain from the river system. This is likely to have contributed to the poor environmental condition of Tea Garden Creek noted by the Scientific Panel in its visit in November 2000.

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 (Koehn and Nicol 1998). The Murray cod from Lake Mulwala have been shown to use the Ovens River on spawning migrations. Hence it is important to view the river system as a continuous system in management terms.

5.5.4 Fish stockings

Both native and introduced fish species have been stocked into the Ovens River system (Appendix 2). Murray cod, trout cod, golden perch and Macquarie perch and have all been stocked or translocated into the study area, while Brown and Rainbow trout have been stocked into the upper river reaches. The major stocking effort has been for the introduced trout species, with over 2.5 million being stocked into the study area since the early 1890s. A small number of Chinook Salmon were also stocked into Lake Catani in 1936-37.

The stocking of native fish in recent years has concentrated on Trout cod, with attempts to establish a population downstream of Wangaratta. Macquarie perch have been both stocked and translocated into the study area, but there is no evidence that any population remains. The effect of stocking of Murray cod and Golden perch are not known.

5.5.5 Fish Kills

The EPA at Wangaratta has 9 records of reported fish kills in the Ovens catchment from 1997, five of which occurred in the study area. Details of these instances are given in Appendix 3. Most relate to high water temperatures, water extraction or poorly handled pesticides.

5.5.6 Cold Water Releases

Water temperature plays an important role in fish biology, particularly for reproduction, optimal functioning and growth. The native fish present in the study area can be described as 'warmwater' species, as they generally require stream temperatures greater than 16^{o}C for optimal spawning (Koehn *et al*. 1995) (Appendix 3). The release of cold water from water storages poses a major problem to 'warmwater' fish, as it may restrict the success of fish spawning or have detrimental effects on metabolic function and growth rates. As stated in section 5.2.1, a preliminary assessment of cold water releases from Lake Buffalo and Lake William Hovell suggested that there may be cold water releases from Lake Buffalo in some years (Appendix 3). The occurrence of cold water releases from Lake William Hovell, if any, was less clear. The potential for cold water releases from the two dams is currently being investigated by DNRE.

5.5.7 Fish habitat

Overbank flooding has been linked to the successful recruitment of many native fish species. While flooding may not be essential as a spawning stimulus, it is considered to enhance phytoplankton production, provides cues for migration, and enhances access to a wide variety of habitats (McKinnon 1997). The unregulated nature of river flows and access to the floodplain means that the Ovens River is one of the few remaining rivers in Victoria where flooding can occur in a relatively natural setting. Although little research has been conducted, many native fish species utilise the floodplain to exploit the abundant food resources when it is flooded.

Snags or large woody debris are the major form of structural habitat in lowland rivers and are widely used by many fish species. The use of this habitat has long been recognised, but recent research has shown that the importance of snag habitat has probably been underestimated (Koehn 1997, Koehn and Nicol 1998). Snags are used as:

- Home sites around which fish form territories;
- Areas in which fish seek protection from high water velocities and predators;
- Areas in which to seek prey;
- Major sources of food; and
- Spawning sites for many species.

The number of snags needed to maintain fish populations varies but overall, snag numbers (particularly upstream of Wangaratta) are considerably less than those that occurred naturally, and more snags can provide habitat for more fish. Habitats in the form of pools and scour holes can also be lost through infilling and sedimentation. Removal of snags and bank erosion can lead to a more uniform channel with a reduced diversity of habitats. Variations in depth and velocities are important to provide the habitat needs for the native species present and their various life stages. The presence of snags promotes such habitat diversity.

Recent study of the properties of snags in the mid Murray River by Koehn *et al*. (2000) indicate:

- A mean snag density of 1.82 snags per 10m^2 of river bed;
- Most snags were full trees or at the very least trunks;
- Orientation was perpendicular to the banks;
- Average length was 22.7 m;
- Mean diameter was 1.67m.

These may be useful figures from which to judge the adequacy of snag numbers in the Ovens River, and on which to base any resnagging activities.

5.5.8 Fish recruitment

It has been hypothesised that some species of fish in the Murray Darling Basin take advantage of extended periods of low flow to spawn because of the presence of appropriately sized prey (Humphries *et al.* 1999). Smaller volumes of water, warmed by summer temperatures, favours the concentration of prey (e.g. zooplankton, benthic invertebrates) to sufficient densities to allow feeding by fish larvae, especially in still habitats such as backwaters and pools.

Seasonal flow inversions, such that occur in summer-autumn period, and unseasonable flows (e.g. the supplementary flows to the Murray River that occur for a number of weeks – cf short term pulse expected with a summer storm) may increase the risk of dispersing both fish larvae and their food source and so reduce the chance of successful fish recruitment. However, further research is required to confirm the ‘low flow recruitment hypothesis’ and which species it may apply to the Ovens River system.

The generation of hydroelectricity at Lake William Hovell may result in rapid fluctuations in water level in the King River below the dam. This may result in rapid changes to the habitat available to native species such as two-spined blackfish and increases the risk of egg stranding when this species spawns between October and December (Koehn and O’Connor 1990).

5.5.9 Impact of river regulation on fish populations

River regulation is likely to have impacted on fish populations in the following ways:

- The presence of dams and weirs serve as barriers that stop the migration of native fish species;
- The potential release of cold water from the dams that may affect fish spawning, distribution and biology (e.g. growth rates);
- The rapid fluctuation of water levels below Lake William Hovell associated with generation of hydroelectricity may result in rapid changes to the habitat available for species such as two-spined blackfish, and an increased risk of stranding of eggs following spawning. This risk will decrease with distance downstream due to tributary inflows;
- The availability of habitat critical for maintaining threatened species such as Murray cod, may potentially be reduced due to reduced low flows in the lower Ovens River (reach 5). This is an issue requiring further investigation;
- Seasonal flow inversions or unseasonable flow pulses (e.g. supplementary flows to the Murray River) may increase the risk of disrupting recruitment by displacing fish larvae and their food sources.

5.6 Threatened Species

A total of 39 fauna (including 26 bird and 9 fish species) and 9 flora species listed as threatened have been recorded in or adjacent to the rivers across the study area (DNRE, unpublished data). An additional fish species, silver perch (*Bidyanus bidyanus*) has also been noted in section 5.5.2. Many of the 26 threatened bird species are vulnerable due to a decrease in available habitat. For example, the Regent honeyeater and Swift parrot feed in yellow-box and ironbark woodlands and river red gum forest, such as that growing along the lower reaches of the Ovens and King Rivers. Other bird species are likely to be attracted by billabong and wetland habitat.

The threatened fish species are the subject of ongoing management efforts, and management plans have or are being prepared for species such as Murray cod, catfish and silver perch. Potential threats related to the survival of threatened fish species were discussed in section 5.5.

5.6.1 Impact of river regulation on threatened species

The impact of regulation on threatened fish species was outlined in section 5.5.9. Regulation of flow from the dams is unlikely to impact of threatened bird, mammal, amphibian and reptile species, which are mainly affected by reduced habitat availability or a decline in habitat quality. These issues are mainly affected by the presence of levees and other catchment management practices, rather than changes to the flow regime.

Table 12: Threatened species recorded in the study area (from DNRE, unpublished data)

Common Name	Species	FFG	AROTS	VROTS	TWV	ESP
Reach 1 Buffalo River from Lake Buffalo to the Ovens River						
Great Egret	*Ardea alba*	L			End	
White bellied sea eagle	*Haliaeetus leucogaster*	L			End	
Trout cod	*Maccullochella macquariensis*	L			End	End
Murray cod	*Maccullochella peelii peelii*	L				Vul
Macquarie perch	*Macquaria australasica*	L				End
Reach 2 Ovens River from the Buffalo River confluence to the King River confluence						
Squirrel glider	*Petaurus norfolcensis*	L			End	
Great Egret	*Ardea alba*	L			End	
Intermediate egret	*Ardea intermedia*	L			CEn	
Royal spoonbill	*Platalea regia*				Vul	
Nankeen night heron	*Nycticorax caledonicus*				Vul	
Regent honeyeater	*Xanthomyza phrygia*	L			CEn	End
Mountain galaxias	*Galxias olidus*	L			DD	
Reach 3 King River from Lake William Hovell to Edi						
Squirrel glider	*Petaurus norfolcensis*	L			End	
Musk duck	*Biziura lobata*				Vul	
White bellied sea eagle	*Haliaeetus leucogaster*	L			End	
Royal spoonbill	*Platalea regia*				Vul	
Regent honeyeater	*Xanthomyza phrygia*	L			CEn	
Mountain galaxias	*Galxias olidus*	L			DD	
Murray cod	*Maccullochella peelii peelii*	L			Vul	
Macquarie perch	*Macquaria australasica*	L			End	
Warty bell frog	*Litoria raniformis*				Vul	
Caddis fly	*Archaeophylax canarus*	L			R/R	
Reach 4 King River from Edi to the Ovens River confluence						
Squirrel glider	*Petaurus norfolcensis*	L			End	
Great egret	*Ardea alba*	L			End	
Intermediate egret	*Ardea intermedia*	L			CEn	

Common Name	Species	FFG	AROTS	VROTS	TWV	ESP
Little egret	*Egretta garzetta*	L			CEn	
Royal spoonbill	*Platalea regia*				Vul	
Nankeen night heron	*Nycticorax caledonicus*				Vul	
Bush stone curlew	*Burhinus grallarius*	L			End	
Glossy black cockatoo	*Calyptorhynchus lathami*	L			Vul	
Barking owl	*Ninox connivens*	L			End	
Regent honey eater	*Xanthomyza phrygia*	L			CEn	
Magpie goose	*Anseranas semipalmata*				End	
Australasian shoveller	*Anas rhynchotis*				Vul	
White bellied sea eagle	*Haliaeetus leucogaster*	L			End	
Musk duck	*Biziura lobata*				Vul	
Glossy ibis	*Plegadis falcinellus*				Vul	
Black bittern	*Ixobrychus flavicollis*				CEn	
Trout cod	*Maccullochella*	L			CEn	End
	macquariensis	L			Vul	
Murray cod	*Maccullochella peelii peelii*	L			End	
Macquarie perch	*Macquaria australasica*	L			DD	
Mountain galaxias	*Galaxias olidus*					
Button rush	*Lipocarpha microcephal*				v	
Summer fringe sedge	*Fimbristylis aestivalis*				k	
Tall club sedge	*Bolboschoenus fluviatilis*		V		v	
Reach 5 Ovens River from the confluence with the King River to the Murray River.						
Regent Honeyeater	*Xanthomyza phrygia*	L			End	CEn
Great Egret	*Ardea alba*	L				End
Little egret	*Egretta garzetta*	L				CEn
Barking Owl	*Ninox connivens*	L				End
Powerful Owl	*Nonox strenua*	L				End
Bush stone curlew	*Burhinus grallarius*	L				End
Blue-billed duck	*Oxyura australia*	L				Vul
Turquoise parrot	*Neophema pulchella*	L				LR
Brown quail	*Coturnix ypsilophora*					DD
Nankeen night heron	*Nycticorax caledonicus*					Vul
White bellied sea eagle	*Haliaeetus leucogaster*	L			End	End
Swift Parrot	*Lathamus discolor*	L				End
Royal spoonbill	*Platalea regia*					Vul
Painted honeyeater	*Grantiella picta*	L				Vul
Pied cormorant	*Phalacrocorax varius*					LR
Black faced cormorant	*Phalacrocorax fuscescens*					Vul
Whiskered tern	*Chlidonius hybridus*					LR
Australasian shoveller	*Anas rhynchotis*					Vul
Freckled duck	*Stictonetta naevosa*	L				End
Hardhead	*Aythya australis*					Vul
Musk duck	*Biziura lobata*					Vul
Squirrel glider	*Petaurus norfolcensis*	L				End
Crimson spotted rainbow	*Melanotaenia fluviatiis*	L				DD
fish		L			End	CEn
Trout cod	*Maccullochella*	L				Vul
	macquariensis					Vul
Murray cod	*Maccullochella peelii peelii*					DD
Golden perch	*Macquaria ambigua*					Vul
Flat-headed galaxias	*Galaxias rostratus*	L				End
Broad shelled tortoise	*Chelodina expansa*					Vul
Carpet python	*Morelia spilota variegata*					LR
Warty bell frog	*Litoria raniformis*					
Southern myotis	*Myotis macropus*					
Mountain swanson pea	*Swainsonia recta*	L	E	e	E	
Rough eyebright	*Euphrasia scabra*	L	K	e		
River swamp wallaby	*Amphibromus fluitans*	X	V	k	V	

Common Name	Species	FFG	AROTS	VROTS	TWV	ESP
grass				v		
Dookie daisy	*Brachyscome gracilis*			k		
Tall wallaby grass	*Austrodanthonia sp.*	L	V	e	V	
Mueller daisy	*Brachyscome muelleroides*					

5.7 Floodplains in the Ovens System

5.7.1 Background

Over the past decade or more there has been a rapid development in the theoretical understanding of the role of floodplains as part of river ecosystems (Young 2001). Because of the scale at which rivers and their floodplains interact it has been difficult to test some of these theories experimentally, although current research is supporting the thrust of the theories to the point where they can be used as part of a package the best-available knowledge to support management, whilst recognising the necessity of refining knowledge as new information is provided.

Carbon is the basic currency of ecosystems. It is the basis of all food chains and its synthesis into organic forms (photosynthesis; primary production) and the ways in which it is exchanged through the food web determines the productivity, biodiversity, and robustness of the ecosystem. The sources and forms of carbon in river ecosystems are many. They including leaves and litter from upper catchments, in-channel production (aquatic plants, algae, and biofilm) in middle reaches, and the products of production on the floodplain (litter, other terrestrial sources, and floodplain wetlands) in the lowland reaches. In the upland reaches, carbon is delivered either by direct input from riparian vegetation or by transport in surface runoff. In floodplain reaches, a delivery system is also required but, as rainfall runoff is much reduced in force and quantity, the process is dependant on connections between the river and floodplain wetlands (billabongs and temporary anabranches) and/or the sweeping of floodplain areas by over-bank flow.

Resource management can threaten and damage this relationship in several ways:

- The reduction of floodplain productivity (in the ecological sense) by clearing, heavy grazing etc. in areas likely to be inundated.
- Degradation of floodplain wetlands (eg draining, blocking, abstraction, heavy stock use).
- Alienation of floodplain by levees
- Flow regulation/water use which changes the timing, frequency, or extent (space or time) of over-bank flows.

Floodplain systems supply more than carbon and nutrients to the river ecosystem. For example, billabongs support microbial communities that are more diverse and far more numerous than the associated river systems. Billabong zooplankton communities are also more diverse and dense (often by two orders of magnitude) than those of the parent river. As well as a massive contribution to biodiversity, floodplain wetlands may serve to inoculate the parent system during high flow events.

The foregoing discussion centres on the essential functional role of floodplains in riverine ecosystems. This is often poorly understood and it is important that resource managers and the community are clear that these functions need to be supported if river health is really an important goal. We should also recognise that floodplains are valuable ecosystems in their own right – contributing significantly to regional diversity.

From previous discussions (Section 5.4) it can be seen that floodplains support a diverse and productive plant community. Floodplains, partly supported by their diverse vegetation, present an array of habitats for other species. Many of these are aquatic organisms adapted to the non-flowing, but often temporary, billabongs and backwaters. The above-mentioned microscopic communities of billabongs are a case in point. Floodplain ecosystems can often be divided into a mosaic of habitats based largely on the frequency and duration of flooding. Work on the Barmah-Millewa forests have identified such sub-habitats and also identified the threats posed to them by changes in water management (Anon. 2000). Each of these sub-units, often characterised by the specific plant communities they support, can be identified by other faunal groups. Even the spatial distribution can be relevant. Parkinson (1996) indicated that diversity of bush-bird species on the Ovens floodplain near Peechelba (Reach 5) was strongly correlated to the proximity of ephemeral wetlands.

In the current study there are three major zones of floodplain located where the Ovens and King valleys broaden and stream gradients are reduced. These are the Ovens and King Rivers upstream of Wangaratta (Reaches 2 and 4) and the Ovens floodplain upstream of the confluence with the Murray.

5.7.2 Reaches 2 and 4.

The floodplains in both of these reaches are significantly modified for agricultural production – mostly grazing. In an ecological sense this has greatly reduced the productivity of these areas and also increased the risk of contamination from grazing stock, applied fertilisers, and the physical effects of rainfall runoff from relatively poorly protected floodplain (note high maximum levels of turbidity in these reaches). Floodplain wetlands also appear often to be severely modified by clearing, grazing and farm watering.

In the upper parts of both of these reaches the narrow floodplain soils have been used for intensive horticulture. Increased land values from this sort of use support intensive ‘river management’ activities to resist bank erosion and avoid floodplain inundation (e.g. levees) even at flows well within the normal range. This severely curtails the ecological role of the floodplain and the loss of its buffering role combined with horticultural practice greatly increases the risk of agricultural chemical contamination (Note the detection of pesticides downstream; section 5.2.2).

Historically levee construction has tended to be ad hoc and maintenance has often been based on the previous existence of the levee or very local (often single-farm) issues. Even current levees appear to be managed at the local government level. Of all land management actions on the floodplain, levees are the most basin-wide in their effect. Prevention of a flood in one area must increase pressures elsewhere and (like dryland salinity) cause and effect are often separated by some distance. Even when leaving ecological considerations aside, decisions regarding levees should be made to the satisfaction of the whole river community, not just in response to individual or local concerns. It follows that a whole-of-system strategy and policy is required. It should include answers to such questions as:

- What are the socio-economic benefits of the levee (and who is the beneficiary)?
- What are the ecological cost/benefits?

- What is the magnitude of the events for which the engineering provides protection (also what is its return frequency –1 in 5 years or 1 in 100 – and to what degree is it inevitable)?

5.7.3 Reach 5.

The parts of this floodplain nearest to Wangaratta are in similar condition to those in reaches 2 and 4. Further downstream, however, levees become less obtrusive, land use becomes much less intense, and floodplain vegetation – at least the larger plants – becomes less modified, denser, and more widespread over the floodplain.

The billabongs and anabranches appear to be in good condition containing fallen timber and diverse aquatic plant communities. The floodplain is relatively narrow in this area with signs of internal benches. Significant proportions of the floodplain are inundated most years in winter/spring. Because of the proliferation of low-profile anabranches, and the flat, confined nature of the floodplain, floods tend to take the form of sheet flows moving longitudinally along the floodplain. Quinn *et al*. (2000) studied 10 billabongs in the vicinity of Peechelba bridges and found that, despite the highly variable morphology of the billabongs, their macroinvertebrate communities showed no consistent difference in response to flooding between previously dry and previously wet sites. Zooplankton communities appear to have increased in density following floods and there is some indication that native fish species used secondary floodways (anabranches) for moving upstream.

It seems most likely that the floodplain in this reach is in a sound functional condition and that this, 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.

5.7.4 Impact of river regulation on floodplains

The overbank flows that are important for connecting the river system with its floodplains has not been altered by flow regulation from the dams. However, floodplain connectivity has been affected by the presence of levees in reaches 2 and 4.

5.8 Summary of environmental values and threats

5.8.1 Ovens in the Murray Darling Basin Context

The Ovens is widely recognised as the least regulated of the major Murray Darling tributaries. From this, if we accept current views on the detrimental ecological effects of large-scale flow manipulation, it is not surprising that the Ovens River system is generally in a healthy condition. This is of particular note, as the pattern of land use on the adjacent floodplain of the Ovens River and its tributaries, especially upstream of Wangaratta, is not markedly different from that on similar streams in the region. An obvious, and as yet unrefuted, conclusion is that the comparative good health of the Ovens (despite major catchment changes) may be attributed to the limited amount of flow regulation, which does not result in significant changes to the natural hydrograph. Thus the Ovens is important not only as an icon river (and demonstration site) throughout Victoria, but also as a functional component of the Murray Darling system. It follows that the managers of the system have a responsibility to avoid risking this status in any of their actions. Significant aspects of the Ovens in the wider context include:

- *Reference Site*. The lower reaches of the Ovens provide the most significant examples of an intact floodplain and in-stream habitat for a lowland river in the Victorian portion of the Murray Darling Basin. As such it provides an extremely important reference site for all projects aimed at restoring habitat and/or flow regimes in other rivers. This includes riverine and floodplain systems.

- *Ecological Resource*. Current research indicates that the Ovens carries a highly significant breeding population of Murray Cod, Golden Perch, and a site for the re-establishment of Trout cod populations, in marked contrast to other rivers in the region. It seems likely that these represent "seed populations" for the rest of the upper Murray system downstream of Hume Dam. The same may apply to a raft of other organisms – particularly those that depend on a 'natural' interaction between river and floodplain.

Under these circumstances, a threat to the lower Ovens ecosystem might well be amplified to be a threat to the Murray system. If, as seems likely, the Murray down-stream of Hume is dependent on the Ovens to prevent its further ecological decline, degradation of the lower Ovens could be magnified throughout the Murray.

The current environmental values and threats identified across the study area are summarised in the following sections.

5.8.2 Summary of environmental values associated with the Ovens River system

Based on the previous discussion of the river system and observations made by the Scientific Panel during its field visit in November 2000, the environmental values to be protected include:

- The Ovens River is one of the last largely unregulated rivers in the Murray Darling Basin and is particularly important as a reference against which to assess the state of other lowland rivers in the region;
- The natural flow regime (including both high and low flows) as it maintains geomorphological, biological and ecological processes;
- Habitat diversity that includes instream features such as abundant large woody debris, cobbles, riffles, pools, bars, anabranches, flood runners and the littoral fringe, and floodplain and wetland/billabong features in the nearby landscape;
- Threatened species (flora and fauna), including up to ten native fish species of State and national conservation significance and icon species such as Murray cod;
- Riparian vegetation, especially in the upper King River and the lower Ovens River, which may serve as a template for future restoration or rehabilitation efforts. The remnant riparian and floodplain vegetation also provides important habitat for threatened species (fish, birds, amphibians) whose natural habitat in the region has been greatly reduced since European settlement. This includes river redgum forest and box woodlands, and herb wetlands such as those occurring adjacent to the lower section of the Ovens River. In particular, lowland riparian habitat is an important refuge for threatened native fish species such as Trout cod and Murray cod;
- Generally good water quality conditions, especially above Wangaratta, that supports river and wetland biota and increases the likelihood of success of river rehabilitation via habitat reinstatement;
- Connectivity between the river channel and its floodplain that maintains floodplain function;
- Links with the Murray River, with the Ovens being important for water yield, water quality and fish migration.

The largely natural flow regime plays an essential role in maintaining the generally good condition of the river system across the study area, as it maintains natural geomorphological processes that in turn create a diversity of habitats for biota, and also helps to maintain good water quality. This close-to natural flow regime also means that important wetland and floodplain areas are inundated in a pattern close to natural with respect to frequency, season and duration of flooding (especially in the Heritage River section of the Ovens River below Wangaratta), thus ensuring the connection between the main river channels and floodplain habitat. The Ovens system is also an important component of the wider Murray River system, especially in terms of its relative contribution to flow in the Murray and its role in maintaining regional biodiversity (e.g. ten of the native species in the study area have some form of threatened status, seven of these are listed under the Flora and Fauna Guarantee Act and five have a national threatened species listing).

Water quality is generally good in the upper reaches of the study area and macroinvertebrate communities in these reaches suggest diverse and healthy conditions. This increases likelihood of successful riparian and fish habitat rehabilitation in the future.

The protection of the above environmental values are consistent with the objectives of the Heritage Rivers Plan for the Ovens River (DNRE 1997) and the priorities of the Northeast Catchment Management Authority (Northeast Catchment & Land Protection Board 1997). Protection of these values can, therefore, be used as a guide for setting environmental management plans at the local and regional level.

5.9 Summary of threats to environmental values

A large number of activities and processes pose threats of varying degrees to the environmental condition of the Ovens River system. This is not surprising given the broad range of activities and land use that occur across the study area. The threats to environmental values include those associated with flow and river management, agricultural and industrial practices and activity, natural ecological processes, and invasion by pest plant and animal species. Environmental threats may be summarised as:

- Rapid changes to water releases from the two dams that rapidly reduces or increases the habitat available for biota;
- The potential for cold water releases from the dams in summer that may limit the biological activity or distribution of river biota;
- The potential for low or zero flows in lower river reaches due to concentrated pumping by diverters at weekends (this needs to be confirmed) or from water releases failing to meet irrigation demand;
- Supplementary flows to the Murray may send unseasonable biological cues to native biota;
- The removal of snags and the clearance of riparian vegetation that helps to stabilise stream bed and banks and provides instream habitat;
- The encroachment of willows that affect channel geomorphology and result in increased erosion, altered habitat, reduced biodiversity, and altered food quality;
- Bed and bank works by local landholders and previous gravel extraction that has reduced stream habitat diversity and mobilised sediments in the river system;
- Natural bed and bank erosion (exacerbated by bed and bank works undertaken over many decades) that results in increased sediment loads in the river system;
- The infilling of pools by transported sediments, for example in the Ovens River below Myrtleford and the lower King River, that may smother instream habitat;

- Management of Tea Garden Creek, its weir and nearby levees, in a manner that disconnects the creek from its floodplain, reduces the variability of flow entering from the Ovens River and serves as a barrier to fish movement;
- The presence of the Lake Buffalo and Lake William Hovell that serve as barriers to fish movement;
- The presence of carp, trout and other introduced species that compete with, or reduce habitat condition, for native fish species;
- The dominance of weeds such as blackberry and willows over large areas that reduce riparian habitat quality;
- Grazing and watering of livestock in floodplain wetlands and billabongs that reduce water quality and habitat conditions;
- Minor eutrophication and pollutants from urban areas (e.g. Wangaratta) and industrial discharges that may result in less than expected macroinvertebrate families present or contribute to eutrophication downstream in Lake Mulwala;
- Ill-coordinated construction of levees throughout the system – particularly where other responses to high flow may be more ecologically sound.

5.10 Summary of the environmental effects of flow regulation

The effects of flow regulation on the ecological components of the river system may be summarised as:

- River hydrology has been altered, with changes mainly restricted to low-flow periods in average or dry years. This has resulted in increased summer-autumn flows in the Buffalo and King Rivers and reduced summer-autumn flows in the lower Ovens River (the latter increases the potential for reducing instream habitat during critical low-flow periods). A ‘flow reversal’ also occurs in the summer-autumn period, with lower than normal flows in early summer switching to higher than normal flows in late summer-autumn;
- River geomorphology remains largely unaffected by flow regulation;
- Preliminary investigations indicate cold water releases from Lake Buffalo in some years. Apart from potential cold water releases, water quality remains largely unaffected by flow regulation but has been affected by inputs of nutrients and organic pollution, presumably in runoff form agricultural and urban areas;
- The effect of flow regulation on aquatic vegetation is largely unknown and will prove hard to disentangle from other factors without a targeted study. Floodplain wetlands are likely to have been affected by isolation from the river channels (due to levees) and land management practices (e.g. livestock access);
- Macroinvertebrates are unaffected by river regulation in upstream areas. The decline in macroinvertebrate communities in downstream areas is probably due to multiple catchment impacts;
- Native fish populations, including threatened species, have been affected by dams and weirs that act as barriers to migration. The extent of reduced habitat availability due to lower than natural flows in the lower Ovens reach needs to be confirmed. The potential effect of cold water releases from the two dams also requires confirmation, as does the application of the ‘low flow recruitment hypothesis’ and the potential risk of dispersing fish larvae by flows such as supplementary releases to the Murray River;
- The connection between the river channel and its floodplain has been largely unaffected by flow regulation from the dams. However, river-floodplain connections

have been altered by the presence of levees in mid Ovens and lower King River reaches.

Flow and other management recommendations in Chapter 6 will therefore focus on providing low flows to maintain existing fish habitat, particularly for threatened fish species, and other management actions that reinstate of improve habitat available for river and wetland biota.

6 FLOW AND ASSOCIATED MANAGEMENT RECOMMENDATIONS

The following flow and river management recommendations have been developed to maintain the current high environmental or ecological value of the Ovens system and to address a number of the threats to environmental values. In particular, the recommendations aim to protect:

- The natural attributes of the Ovens River, including the largely natural flow regime and the connection of river flows with surrounding floodplain. Given that the Ovens River is one of the few remaining lowland rivers in Victoria with a relatively natural flow regime, its protection must be considered as a high priority;
- Both the natural high flow and low flow events that are recognised as important attributes of the Ovens River.

6.1 Approach to setting flow recommendations

Examination of partial duration series (see section 4.4) and examination of flow duration curves for both high flow (June to October) and low flow (November to May) (Appendix 2) indicated that high flow periods were largely unaffected by regulation, with small decreases at the lower end of the curves due to filling of the dams. The situation for low-flow periods was less clear, with higher than normal flows in summer irrigation periods in the upper reaches (this effect becomes dampened with distance downstream), and lower than normal flows at times of very low flow in the lower Ovens River reach below Wangaratta. Environmental flow recommendations have focussed predominantly on the low flow period of November through to May. No specific flow recommendations are required for the high flow season (June through to October), other than to continue with current dam operations in a fashion that causes as little disruption to natural flows in the Buffalo and King Rivers as possible, especially in terms of preserving flood peaks that flow through the system.

The REALM model provided information that was very useful for assessing the relative changes in the flow regime expected to have occurred since regulation of the system. However, the weekly timestep and discrepancies between modeled and gauged flow means that modeled data (see Chapter 4 and Appendix 1) cannot be relied on as the sole means for setting low-flow environmental recommendations; additional information is required to support the relative differences in flow regimes identified by the REALM model, especially information that relates changes in the flow regime to potential responses by river biota. As maintaining habitat for native fish populations has been given a high priority, the water required to wet instream habitat, in addition to the modeled flow data, was considered to inform the setting of low-flow recommendations. Previous fish habitat work was undertaken by Tunbridge (1988) to inform the establishment of environmental flows for the Ovens River. Transect data from this and other work were available for the following sites:

- Upper, middle and lower King River;
- Three sites on the Ovens River; and
- One site on the Buffalo River.

These data comprised of depth and water velocity measurement at up to 24 transects per site at 2 or 3 different flow levels. Analysis of these data was undertaken to examine its applicability to deliberations of this Scientific Panel. Data were entered into the RHABSIM model and calculations made for wetted perimeter and area (Figure 9). Difficulties were experienced in defining low flow requirements as most of the data were collected at flows higher than those of concern to the Scientific Panel. There is a need for greater resolution of changes to available habitat at low flow (e.g. data for sites on the Buffalo and Ovens Rivers were collected at 65% to 82% exceedance flows; habitat data are required for 90-95% exceedance flows). Data had been collected at a suitably low flow in the King River, but analysis did not indicate a particular point (inflection point) where habitat area declined dramatically and there appeared to be a linear relationship between the reduction in flow and the reduction in habitat area. This may be the result of simplified bed morphology at this site.

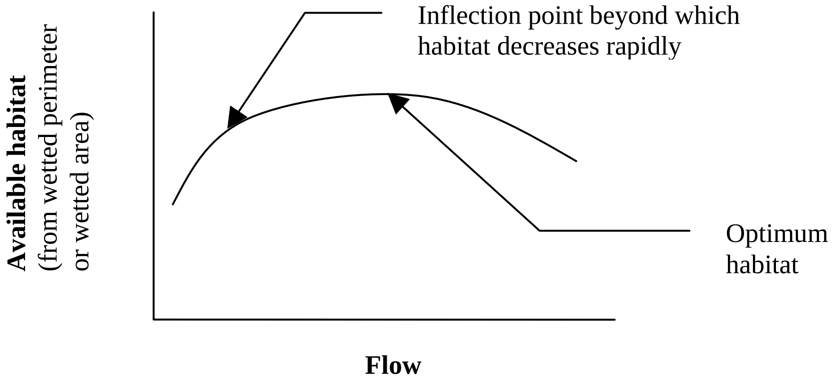


Figure 9: Example of expected habitat versus flow relationships

Ultimately, flow recommendations have been based on low-flow exceedance data (Appendix 2.4) for both gauged (i.e. measured) flows and modelled natural flows provided by the REALM model. In particular, the 95% exceedance and 99% exceedance flows were adopted to set low-flow limits that are likely to maintain habitat for native fish. Given the need for additional work to confirm the low-flow requirements of native fish, the flow recommendations given in the following sections **should be considered as interim values only**. The interim low-flow thresholds recommended are to apply along the entire reach. The 95% exceedance flows for each reach have been used to set minimum flows in each reach during the irrigation season (November to May); i.e., the system should be operated to ensure flows remain above the 95% exceedance flow. The method for setting the flow objectives for reach 5 is presented here as an example:

> Examination of the low-flow exceedance data for reach 5 (Appendix 2.4) indicates that the maximum variation between the current and natural flow regimes occurs at the 90-99% exceedance flows. The 95% exceedance flow for the natural regime has therefore been adopted as minimum flow during the irrigation season. As the data in Appendix 2.4 are weekly data, the 95% exceedance flow has been divided by seven to establish a minimum daily flow (i.e. the 95% flow of 981 ML/week becomes 140 ML/d).

6.2 Flow recommendations for representative reaches

In general the Ovens River is in good environmental condition, although improvements can be made and additional measures are required to protect values such as threatened species and improve instream and riparian habitat. The diversion of water to meet current irrigation demand has had relatively little impact on the river system when compared with the impacts of other catchment activities or processes. The following flow recommendations are based on the assumption that irrigation demand remains at current levels and apply to the low-flow period (November to May).

High flow periods have largely been unaffected by regulation and in many instances; the low-flow recommendations given below are already being met with current operation. The recommendations below generally deal with relatively minor modifications to the flow regime that aim to provide a greater level of protection to the environmental values stated in section 5.8.2.

Factors that may affect the delivery of low flows in the future include climate effects, afforestation in upper catchment areas, and the streamflow management plan currently being developed for the unregulated sections of the Ovens catchment. It is important that the Ovens BE Group establish a process for reviewing environmental flows in the regulated section of the Ovens catchment in light of any new information that emerges on these issues.

6.2.1 Buffalo River below Lake Buffalo

As the flows that connect the river with floodplain and riparian areas are largely unaltered by regulation, the flow recommendations for the Buffalo River have been set to maintain habitat suitable for native fish species, both in the Buffalo River and downstream in the Ovens River. The flow recommendations are also intended to minimise the ‘flow reversal’ effects described in chapter 4 (i.e. to better match the low-flow regime in dry and average years with that of the natural flow regime) and minimise the risk associated with unseasonable flow pulses such as the Murray River supplementary flows.

For the Buffalo River below Lake Buffalo (reach 1):

- It is recommended that flow exceeds 60 ML/d (equivalent to the natural 95% exceedance flow) between November and May;
- Once the dam has filled, releases early in the irrigation season (November to January) should be based on inflows to the dam plus current irrigation and urban demand. This will reduce the impact of diversions on ‘run of the river’ flows, avoids the rapid reduction in flows to below that which occurs naturally and reduces the ‘flow inversion’ effect that occurs in many years;
- The flow recommendations should be reviewed in light of a fish habitat/environmental flows survey conducted at low flows (i.e. 90-95% exceedance flows or approximately 60 ML/d).
- Given the uncertain effect on river biota of releasing supplementary flows to the Murray River, these releases should be minimised or ceased where possible. The potential effect of unseasonable and prolonged flow pulses requires further investigation.

6.2.2 King River below Lake William Hovell

Flows that connect the river channel with floodplain, wetland and riparian areas have largely been unaffected by regulation. As for the Buffalo River, flow recommendations for the King River have been set to maintain habitat suitable for native fish species, both in the King River and downstream in the lower reach of the Ovens River. It is also the intention to minimise the ‘flow reversal’ effects described in chapter 4 (i.e. to better match the low-flow regime in dry and average years with that of the natural flow regime) and minimise the risk associated with unseasonable flow pulses such as the Murray River supplementary flows.

Flows released from Lake William Hovell during the irrigation season are designed to meet demand along the entire King River. Flows released to meet requirements at the Docker Rd Bridge (reach 4) will therefore ensure compliance at Cheshunt (reach 3).

For the King River at Cheshunt (reach 3):

- It is recommended that flow exceeds a minimum of 20 ML/d (equivalent to the natural 95% exceedance flow) between November and May;
- Once the dam has filled, releases early in the irrigation season (November to January) should be based on inflows to the dam plus current irrigation and urban demand. This will reduce the impact of diversions on ‘run of the river’ flows, avoids the rapid reduction in flows to below that which occurs naturally and reduces the ‘flow inversion’ effect that occurs in many years;
- The low flows must be reviewed and refined if necessary in light of a fish habitat/environmental flow survey conducted during suitably low flow conditions. The survey should also consider rapid fluctuations in river level associated with dam operation for hydroelectricity generation and the potential for reduced habitat for native fish and macroinvertebrates and for the stranding of eggs following spawning by river blackfish or two-spined blackfish.

For the King River at Docker (reach 4):

- It is recommended that flow exceeds 40 ML/d (equivalent to the natural 95% exceedance flow) between November and May;
- Once the dam has filled, releases early in the irrigation season (November to January) should be based on inflows to the dam plus current irrigation and urban demand. This will reduce the impact of diversions on ‘run of the river’ flows, avoids the rapid reduction in flows to below that which occurs naturally and reduces the ‘flow inversion’ effect that occurs in many years;
- The interim low-flows should be reviewed in light of the findings of a fish habitat/environmental flow survey conducted at suitably low flows.

6.2.3 Ovens River below the Buffalo River confluence

The flow regime of the Ovens River between the Buffalo River confluence and the King River confluence has largely been unaffected by flow regulation in the Buffalo River. The intention of the flow recommendations for this reach is to maintain the largely natural flow regime that exists, both for high and low-flow periods.

For the Ovens River at Rocky Point (reach 2):

- It is recommended that flow exceeds 154 ML/d (equivalent to the natural 95% exceedance flow) between November and May;
- The interim low flows should be reviewed to reflect changes (if any) to flows in the Buffalo River resulting from a fish habitat/environmental flow survey and the recommendations of the streamflow management plan being developed for the unregulated upper Ovens River catchment

The high flows in the Ovens River below Wangaratta that connect the river channel with riparian, wetland and floodplain areas have not been affected by regulation. As regulation has decreased the low-flows passing through this reach, the intention of the following flow recommendations is to protect the instream habitat of key native fish species listed as threatened in Victoria (or nationally). Further survey work is required to confirm the minimum flow requirements and to identify the minimum flows required of important aquatic macrophytes, should any be present.

For the Ovens River below Wangaratta (reach 5):

- It is recommended that flow exceeds a minimum of 140 ML/d (equivalent of the natural 95% exceedance flow) between November and May.
- The interim low-flow recommendation must be reviewed in light of fish habitat survey work in this reach and the recommendations of the streamflow management plan being developed for the unregulated upper Ovens River catchment.

6.2.4 Priority reaches for maintaining environmental flows

In changing current regulation practices to meet environmental flow recommendations, priority should be given to the protection of the lower Ovens River (reach 5), even if summer releases have to be increased in the upper river reaches. Higher flows in the upper reaches in summer (especially if releases are colder than natural) increases the potential habitat available for introduced brown trout, which competes with native species. The opinion of the Scientific Panel is that increased summer flows in the upper reaches are likely to be less detrimental than the loss of habitat that might result from very low flows in the lower Ovens, which is known to support many threatened species. However, other options for achieving low flow requirements in the lower Ovens should be explored (e.g. identify water use efficiencies for Wangaratta) before additional flows are released from the dams.

6.3 Other Management Recommendations

The generally good condition of the Ovens River system could be improved further by actions that complement the safeguard of the largely natural flow regime. These include habitat rehabilitation works, implementation of existing catchment management and water quality strategies and a review of levees required to protect key infrastructure. The ongoing maintenance or improvement to environmental conditions in the Ovens River system will be bolstered by:

- Giving the lower Ovens River greater status and protection as a natural reference site and a site for scientific merit and study, and in light of its Heritage River status;
- Listing the lower Ovens River as a critical habitat for Murray cod in Victoria;
- Supporting ongoing attempts to re-establish trout cod populations in the Ovens River;
- Removal of the weir on the Ovens River at Tea Garden Creek and pump water to users;
- Removal of the barrier on the Maloney’s Creek;
- Taking care to avoid significant reductions in flow associated with weekend pumping by diverters;
- Instream habitat work, especially in reaches 2 and 3, to improve habitat for fish;
- Implementation of the Ovens Basin Water Quality Strategy;
- Implement the national carp management strategy within the Ovens River basin;
- A basin-wide review of the status, policy, and criteria for levee construction, maintenance, removal.

6.4 Winter Diversions

The Scientific Panel was asked to consider the diversion of 5 GL as a contingency to supply water to irrigators near the Warby Range. This raises a number of potential environmental concerns. For example, to meet the extra demand without impacting on the security of supply of existing diverters may require an increase in the storage capacity of one or both dams. This will mean that a greater proportion of annual flow will be captured, which in turn can reduce the frequency of ecologically important flows (e.g. small to medium flow pulses important for maintaining instream habitat diversity and water quality). Extra demand and a further increase in summer flows also increase the likelihood of ‘flow inversion’ effects in the river system (higher than natural summer flows, lower than natural winter flows). Increased summer releases may also increase the severity or extent of any cold water releases from the dams and reduce the natural variability in the flow regime that is considered to play an important part in maintaining generally good stream conditions.

The Scientific Panel, as a first preference, recommends that the ‘ecological icon’ status of the present flow regime be recognised and that no further diversions be made from the Ovens system. If this is deemed unattainable, then the Panel recommends that any further water extraction from the Ovens River should be taken from high flow events (preferably at Wangaratta where the 5 GL diversion is a relatively small component of total flow) and pumped to an off stream storage, rather than by expansion of existing storages and increased discharge during the irrigation season. In this way, the flow regime will be protected by minimising the increased summer flows that already exist, and taking the 5 GL at a time when this volume is a relatively small part of the discharge in the river. Any diversions should only occur after possible impacts on flows in the Murray and associated wetlands (e.g. Barmah forest) are first considered.

Diversion rules will be required to allow winter diversion from the Ovens River below Wangaratta. Diversions should not commence until flows in the river have exceeded 2,000 ML/d. Diversion flows should be, for example, 5% of river flow on the rising limb of the hydrograph. Diversion should cease when the hydrograph at Bright or Myrtleford begins to fall (Figure 10), thus protecting flood peaks that will be important for reaching valuable downstream wetland and floodplain areas. Further modelling is required to develop an optimal diversion rate that ensures the winter storage is filled with minimal disruption to the flows in the river. Diversion should cease when the hydrograph at Bright or Myrtleford begins to fall and may commence again (if required) upon resumption of a rising limb (assuming the 2,000 ML/d threshold is exceeded).

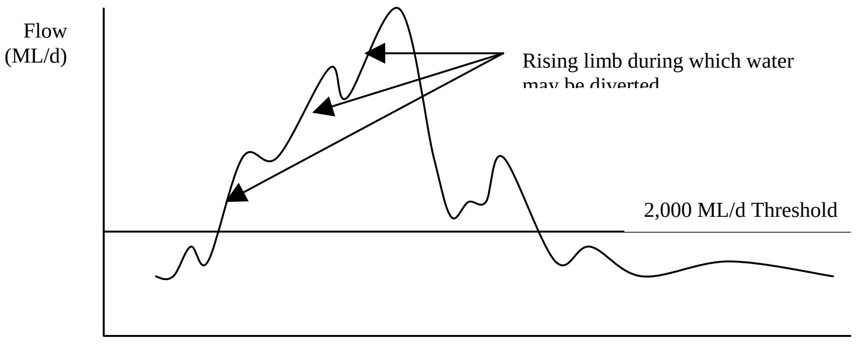


Figure 10: Example of winter diversion from the Ovens River below Wangaratta

6.5 Key knowledge gaps

Confirmation of low-flow recommendations for the lower Ovens and King Rivers require additional fish habitat surveys at very low flows (i.e. complete the RHABSIM work started as part of this study). This work should be undertaken at the earliest opportunity and the results used to update environmental flow requirements in the Ovens Bulk Entitlements.

Cold water releases from the dams have the potential to confound the effect of environmental flows, especially for fish. It is recommended that the potential for cold water releases be investigated, along with the potential extent of their impact downstream of Lake William Hovell and Lake Buffalo. Data were not available to determine the potential frequency or duration of cold water releases from the dams.

It is recommended that potential changes to river flow that occurs with concentrated pumping for diversion on weekends and at night be investigated. Current data are insufficient to determine whether this is a problem, as there are few gauging sites (e.g. the King River at Docker) where this effect might be detected. The presence of anabranches (ungauged) and diversion from pools may also obscure the extent of this problem.

The reasons for the lower than expected number of macroinvertebrate families in the lower Ovens River is not clear. Further investigation is required to determine the factors that are affecting macroinvertebrate communities in the lower Ovens River, with particular attention to pollutants.

There is a lack of information on distribution or ecology of in-channel macrophytes and riparian vegetation. Further investigations are needed to provide map vegetation communities, identify the recruitment requirements of woody riparian species, and assess the seasonal responses of in-channel macrophytes.

An important consideration for the implementation of any or all of the initiatives listed in sections 6.2, 6.3 and 6.4 will be the establishment of a performance monitoring and assessment program to ensure that environmental values are protected and to assess the response of the river system to future management actions (e.g. riparian rehabilitation, additional winter diversion should this occur). While important components of the river system are already monitored (e.g. hydrology, water quality, biological health using macroinvertebrates), there is no routine monitoring for components such as geomorphological changes, fish, and aquatic or riparian vegetation communities. Responsibility for undertaking the various management actions and for assessing their effect will require negotiation between stakeholders such as the NECMA, DNRE, GMW, EPA and local communities.

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APPENDIX 1 OVERVIEW OF THE OVENS REALM MODEL

The Ovens River REALM model (SKM 1998) was originally developed by Sinclair Knight Merz (then HydroTechnology) in 1995 and ran from April 1891 to June 1993 with a weekly time step. The model base case represents irrigation demands at the 1990/91 level of development and the restriction policy and operating rules which applied in 1990/91. This model is referred to as OVENSDRP.SYS.

In 1997, a number of modifications were made to the model to better reflect the Ovens River system, especially water losses along the Ovens River and inflows from Fifteen Mile Creek. The base case model used to assess flow scenarios by the Ovens Scientific Panel represents the 1990/91 level of development. However, it has recently been updated to include the existing system operating rules, including supplementary releases to the Murray system, and restriction policies. This model is referred to as OVENS009.SYS. Operating procedures at Lake Buffalo and Lake William Hovell vary over time. Demand is not constant and a fixed representation of demand based on 1990/91 level of development introduces additional modelling inaccuracies. Because of these factors the simulation outcomes do not directly replicate the gauged data, especially at low flows.

The current model configuration, OVENF020.SYS, could be further enhanced to improve the model calibration with refinement of river loss functions used during high flow conditions. This potential improvement has only been identified since the start of this project.

Another source of discrepancy between modelled and gauged flows is the model rules for releases from Lake Buffalo and Lake William Hovell to provide River Murray supplements. Operational practice has varied over time and it is not practical to model the timing and magnitude of supplement releases from the Ovens system due to the complexity of the River Murray requirements.

Another potential limitation in the use of the REALM model for evaluating environmental flows is the model's weekly time step (recognising that the model was not developed with this purpose in mind). Modelling at a weekly time step, rather than on a daily timestep, increases the risk that short term but significant variations in flow are missed in an analysis. A comparison of the Coefficient of Variation (CV) for the weekly and daily flow (i.e. gauged) data sets for the Buffalo River below Lake Buffalo (1980-1993) was therefore undertaken to examine whether there were potentially significant losses of information if the weekly data were the sole basis for examining flows. While the weekly flow data set (CV = 1.49) was less variable than the daily flows data set (CV = 1.62), statistical analysis indicated that the difference in CV was not significant at the 5% level ($X^2_{(0.05,1)} = 0.64$, $p = 0.448$) (Zar 1996). A similar pattern was found for the King River at Cheshunt (daily flow CV = 1.54, weekly flow CV = 1.34).

Although there was no statistically significant differences in the variability of the modelled and gauged data sets, some subtle differences emerged upon further examination of the data to establish how much error is introduced into the analysis by using an average weekly as opposed to a daily average or instantaneous maximum flow. This was considered important - because the peak of a hydrograph is likely to be shorter than one week, weekly averages may not be representative of either the high or low end of the flow series.

Errors introduced by using weekly averages were investigated by comparing the average daily flows for the Buffalo River gauge at the Buffalo Dam (403022) with modelled weekly average flows for an average year – 1986. This was done by simply dividing the weekly flows by seven. The results (Figure 11) show that the weekly modelling does follow the general trend of the daily record, but that there are important differences. The timing of the peaks and lows does not always correspond. This is not a serious problem because our study is not concerned with the timing of daily flows. Of more concern is the representation of high and low peaks. The peaks of the daily averages can be half of the flood peaks (e.g. 9000 ML/d versus 18,000 ML/d) (Figure 11). In terms of stage, this difference represents a difference in flow level between 1.5 and 3m, and so a large difference in habitat if managers were to use a PHABSIM type model to estimate the habitat available under various flows.

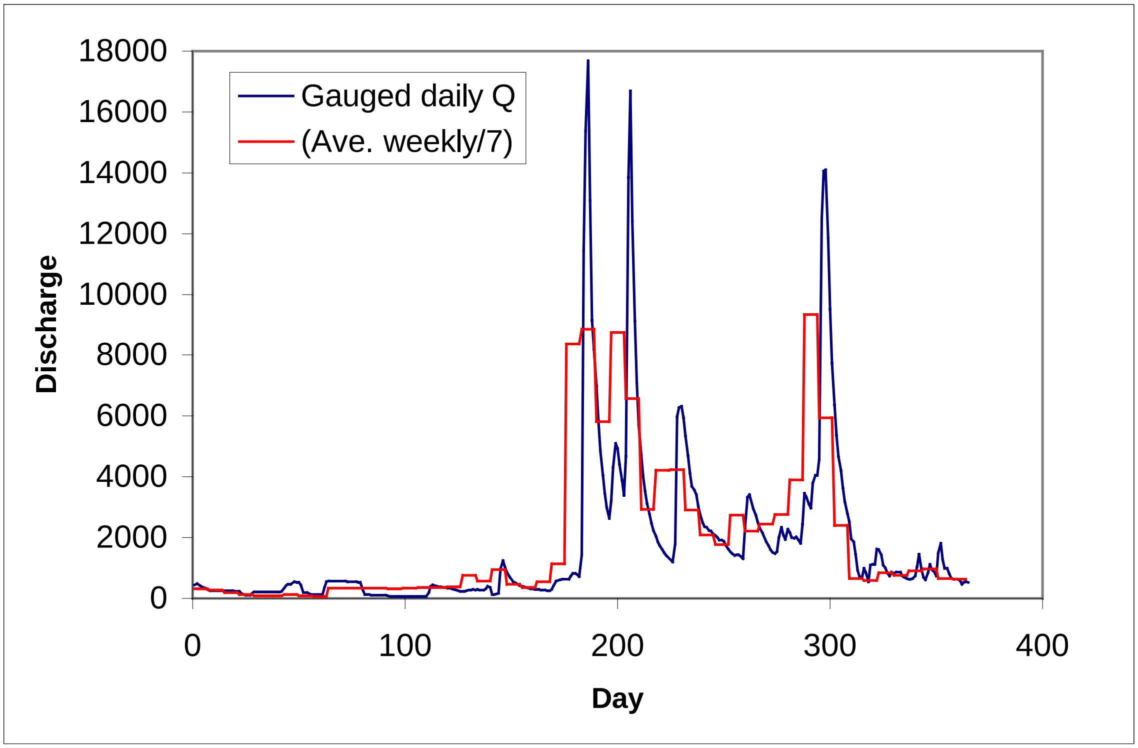


Figure 11: **Buffalo River at Lake Buffalo (403220). Comparison of daily flows in 1986 with modelled average weekly flows divided by seven.**

In proportional terms, the weekly series tends to underestimate the largest daily peaks by almost a factor of two (Figure 12). However, gauged daily flows of most probabilities are smaller than their corresponding weekly average (Figure 12). The implication of this difference is most important at the lower flows. Major floods are unaffected by regulation, even if they are not accurately described by an average weekly flow model. However, low flows are affected by regulation. At flows below about 8,000 ML/d (AEP of about 5%), flows tend to be over-estimated by the weekly model. The implication of this is that the actual magnitude of unregulated daily flows is likely to be slightly less than predicted by the weekly model. This suggests that the weekly model is slightly conservative in terms of the effects of regulation on flows.

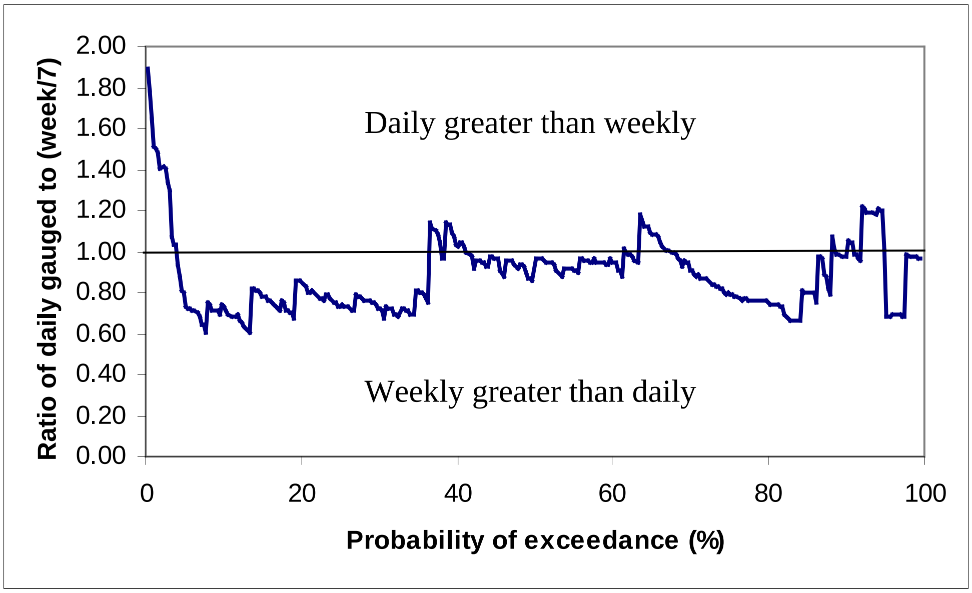
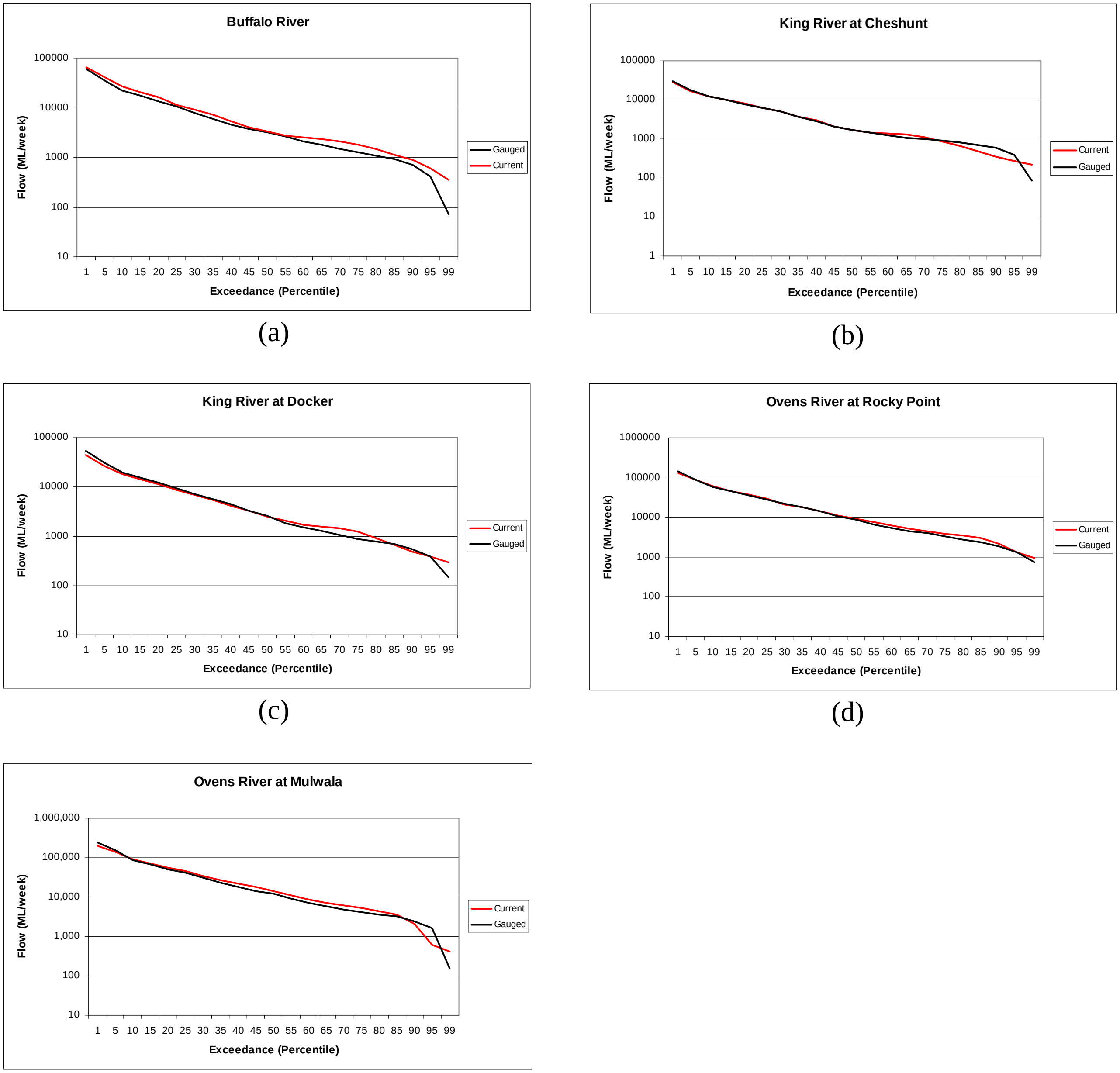


Figure 12: **Ratio of daily gauged flows to weekly modelled flows for 1986 (divided by seven) (Buffalo River gauge, below Lake Buffalo).**

APPENDIX 2: HYDROLOGY OF REPRESENTATIVE REACHES

Appendix 2.1 Comparison of modelled current and gauged flows in the river system 1980 - 1993



(a) (b) (c) (d) (e)

Figure 13: Flow duration curves for (a) Buffalo River below Lake Buffalo (403220) (b) King River at Cheshunt (403227) (c) King River at Docker Rd Bridge (403223) (d) Ovens River at Rocky Point (403230) (e) Ovens River at Lake Mulwala. The curves are based on weekly data collected or modelled for the period January 1980 to June 1993.

Appendix 2.2 Flow duration curves for modeled flow scenarios (1980 – 1993): - natural, current, full entitlement and full entitlement + 5 GL

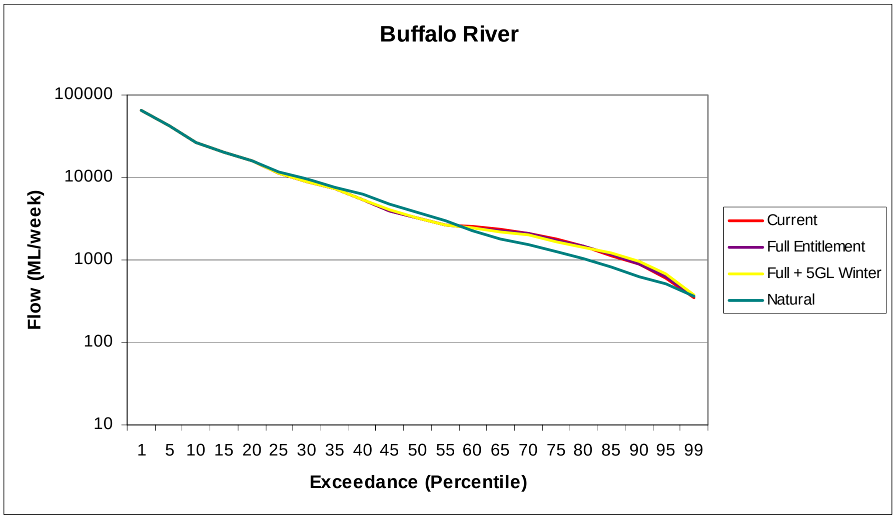
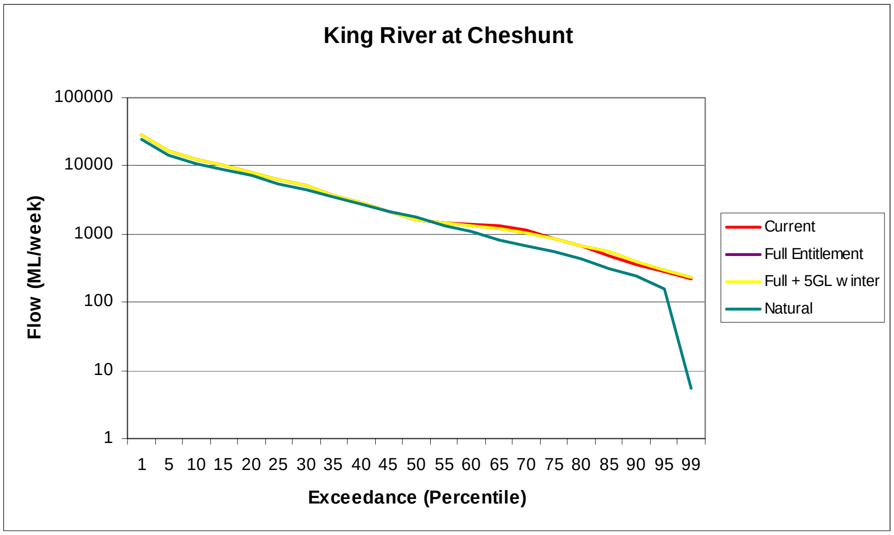
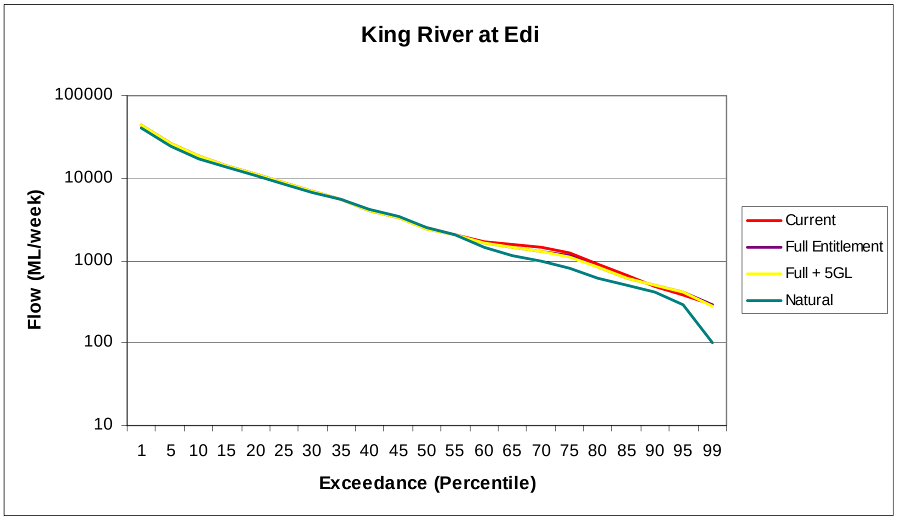


Figure 14: **Comparison of modelled natural with current and potential future water demand from the Buffalo River (site 403220)**





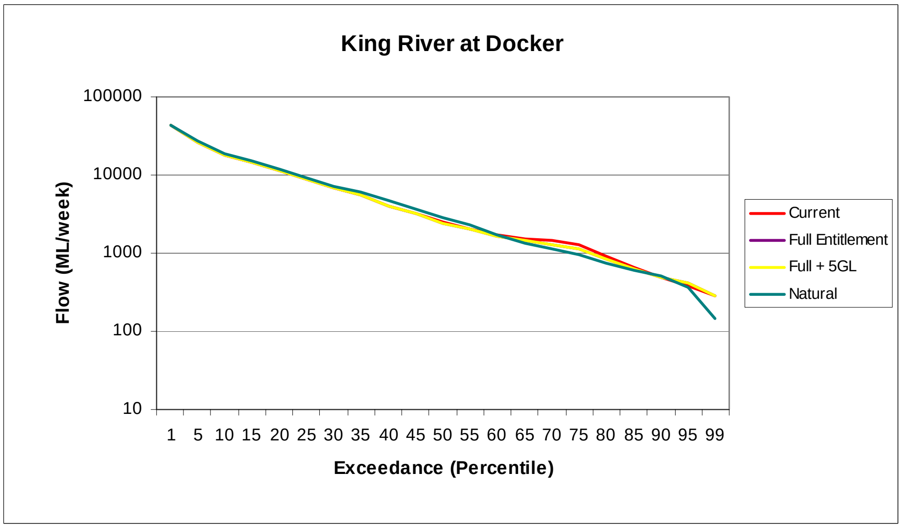
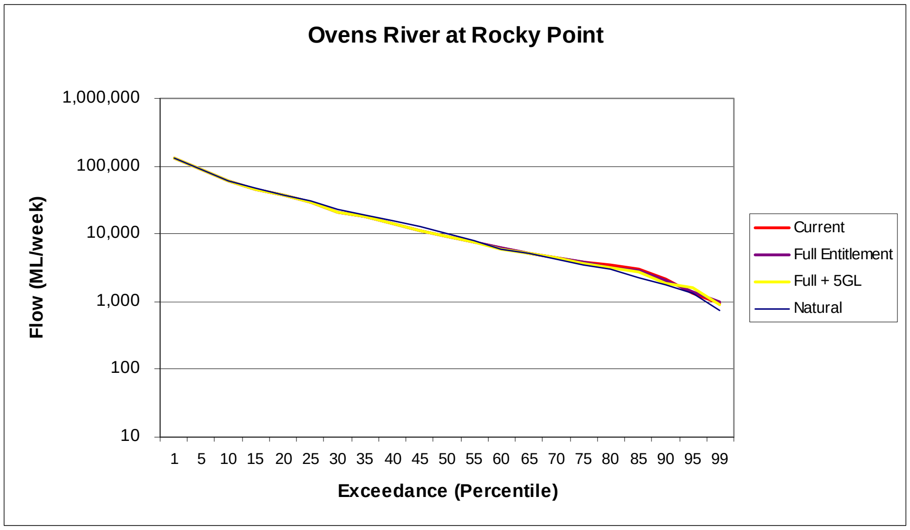


Figure 15: Comparison of modelled natural with current and potential future water demand from King River at Cheshunt (gauge site 403227), Edi (gauge site 403240) and Docker Rd Bridge (gauge site (403223).



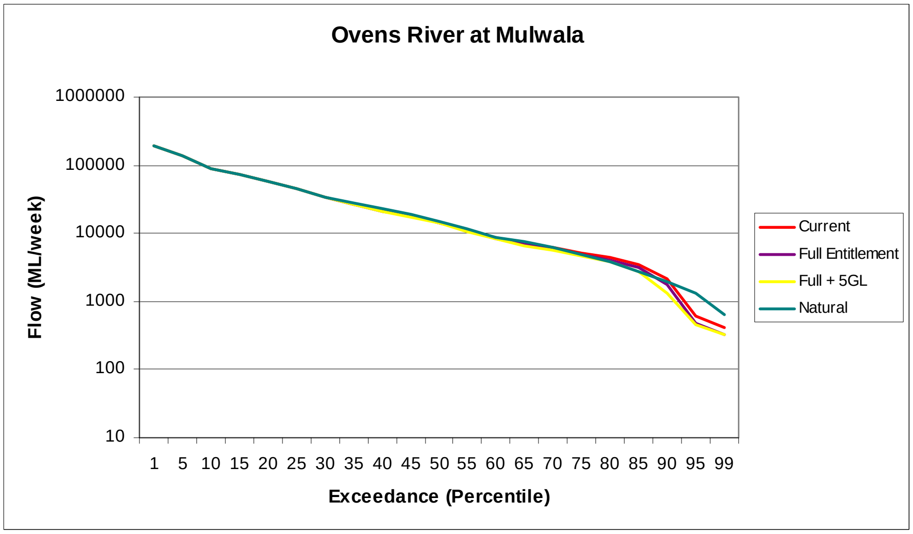


Figure 16: **Comparison of modelled natural with current and potential future water demand from Ovens River at Rocky Point (site 403230) and at Lake Mulwala**.

Appendix 2.3: Flow duration curves for high flow periods (June to October, inclusive), 1980 – 1993

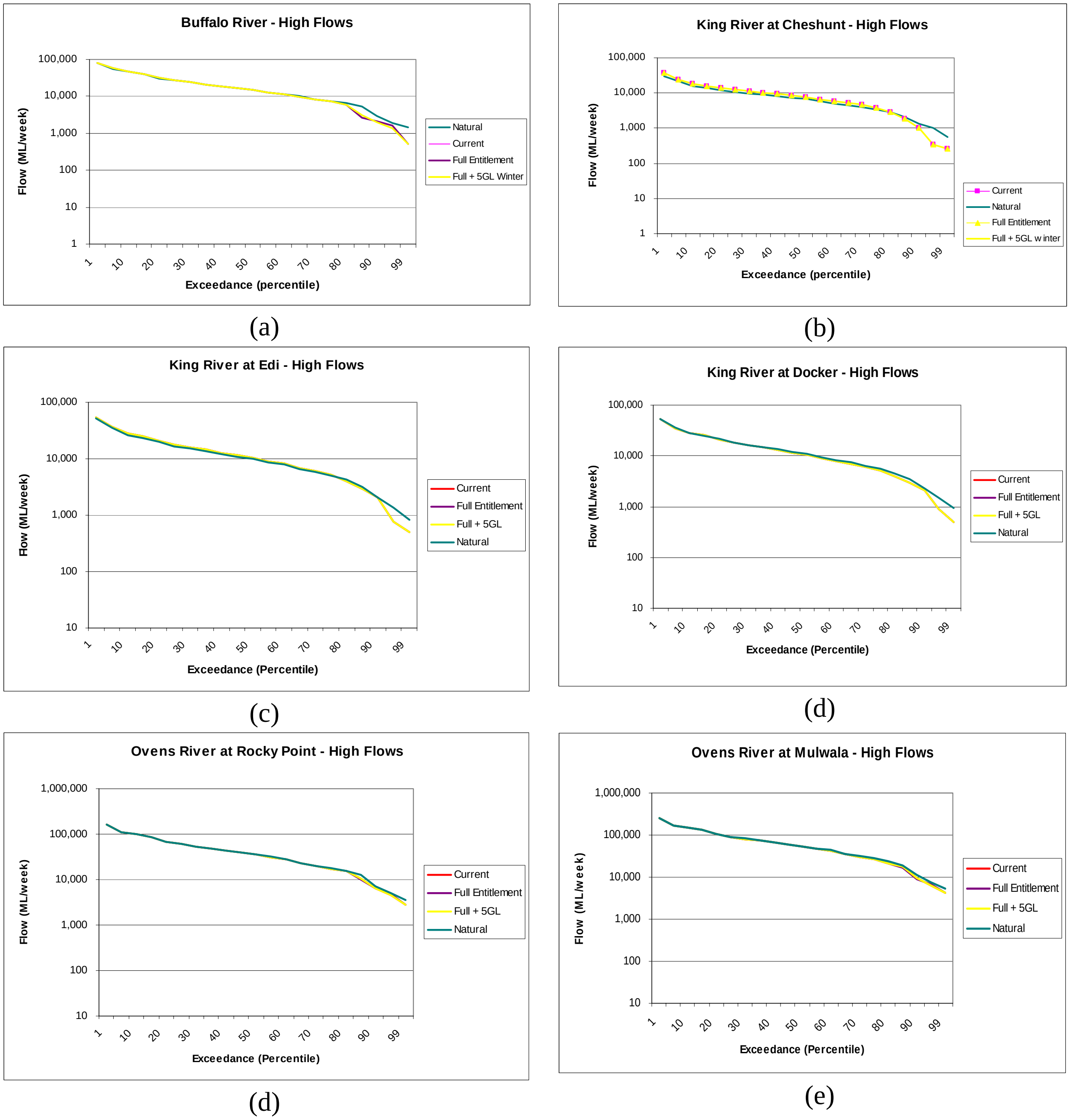


Figure 17: High flow duration curves for (a) Buffalo River below Lake Buffalo (403220) (b) King River at Cheshunt (403227) (c) King River at Edi (403240) (d) King River at Docker (403223) (e) Ovens River at Rocky Point (403230) (f) Ovens River at Lake Mulwala. The curves are based on modelled weekly data for high flow periods (June to October), 1980 to 1993.

Appendix 2.4: Flow duration curves for low-flow periods (November to May, inclusive), 1980 – 1993

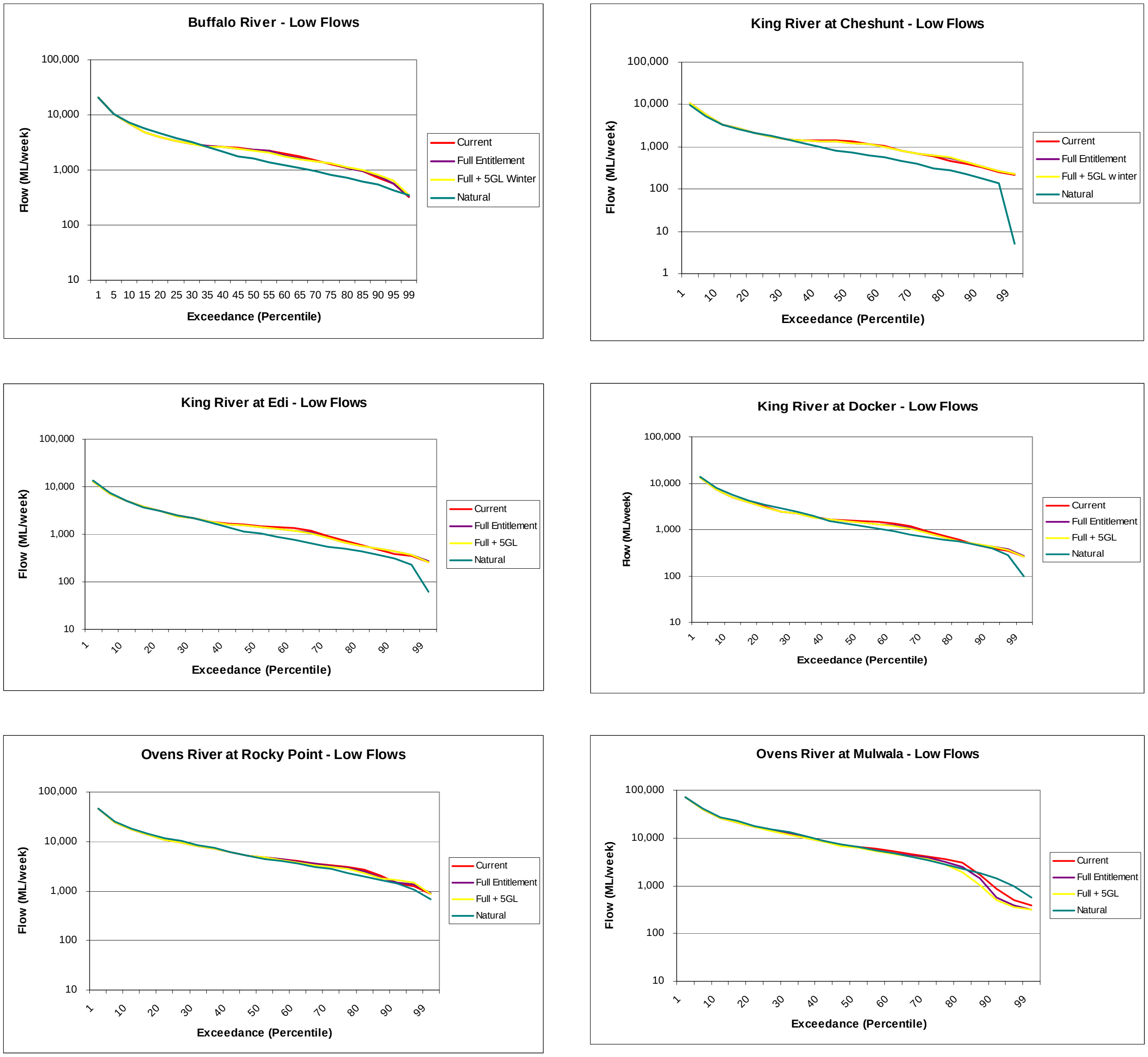


Figure 18: Low flow duration curves for (a) Buffalo River below Lake Buffalo (403220) (b) King River at Cheshunt (403227) (c) King River at Edi (403240) (d) King River at Docker (403223) (e) Ovens River at Rocky Point (403230) (f) Ovens River at Lake Mulwala. The curves are based on modelled weekly data for low-flow periods (November to May), 1980 to 1993.

Table 13: Low-flow exceedance data for the Buffalo River (ML/week), 1980-1993

Flow Exceedance (percentile)	Natural	Current	Full Entitlement	Full + 5GL Winter	Gauged	Current v Natural	Gauged v Natural
1	20,538	20,728	20,728	20,728	19,547	101%	95%
5	10,326	10,301	10,301	10,301	9,326	100%	90%
10	7,342	6,837	6,836	6,836	5,913	93%	81%
15	5,578	4,850	4,848	4,848	4,535	87%	81%
20	4,609	3,986	3,986	3,986	3,761	86%	82%
25	3,738	3,426	3,419	3,419	3,488	92%	93%
30	3,232	3,037	3,037	3,037	2,985	94%	92%
35	2,678	2,705	2,711	2,686	2,660	101%	99%
40	2,145	2,599	2,591	2,587	2,237	121%	104%
45	1,765	2,514	2,444	2,430	2,006	142%	114%
50	1,624	2,369	2,303	2,229	1,790	146%	110%
55	1,373	2,256	2,200	2,064	1,576	164%	115%
60	1,204	1,957	1,826	1,764	1,423	162%	118%
65	1,100	1,741	1,650	1,582	1,281	158%	117%
70	946	1,504	1,466	1,439	1,136	159%	120%
75	827	1,259	1,318	1,321	1,036	152%	125%
80	724	1,096	1,105	1,139	909	151%	126%
85	606	943	944	1,001	728	156%	120%
90	535	733	773	816	554	137%	104%
95	425	563	562	631	394	132%	93%
99	348	319	336	351	48	92%	14%

Table 14: Low-flow exceedance data for the King River at Cheshunt (ML/week), 1980-1993

Flow Exceedance (percentile)	Natural	Current	Full Entitlement	Full + 5GL winter	Gauged	Current v Natural	Gauged v Natural
1	9,573	10,618	10,618	10,618	10,753	111%	112%
5	5,153	5,740	5,740	5,740	5,492	111%	107%
10	3,320	3,363	3,362	3,362	3,545	101%	107%
15	2,561	2,769	2,766	2,766	2,631	108%	103%
20	2,167	2,129	2,129	2,129	2,103	98%	97%
25	1,798	1,770	1,739	1,739	1,825	98%	101%
30	1,462	1,499	1,490	1,490	1,580	103%	108%
35	1,217	1,446	1,435	1,435	1,411	119%	116%
40	983	1,402	1,375	1,375	1,256	143%	128%
45	801	1,377	1,326	1,326	1,161	172%	145%
50	719	1,318	1,205	1,205	1,063	183%	148%
55	624	1,180	1,124	1,124	1,013	189%	162%
60	557	1,035	989	969	944	186%	169%
65	453	810	819	823	896	179%	198%
70	390	684	707	711	818	175%	210%
75	316	607	614	620	769	192%	243%
80	272	463	544	558	713	170%	262%
85	230	394	433	435	651	172%	284%
90	179	318	347	345	536	178%	300%
95	138	257	268	265	355	187%	258%
99	5	213	226	226	74	4263%	1477%

Table 15: Low-flow exceedance data for the King River at Docker Rd Bridge (ML/week), 1980-1993

Flow Exceedance (percentile)	Natural	Current	Full Entitlement	Full + 5GL	Gauged	Current v Natural	Gauged v Natural
1	13,780	12,918	12,918	12,918	15,947	94%	116%
5	8,048	7,170	7,165	7,165	8,458	89%	105%
10	5,619	5,026	5,026	5,027	4,976	89%	89%
15	4,211	3,847	3,846	3,846	4,214	91%	100%
20	3,342	3,065	3,056	3,056	3,337	92%	100%
25	2,844	2,459	2,424	2,424	2,779	86%	98%
30	2,396	2,209	2,193	2,193	2,270	92%	95%
35	1,989	1,866	1,805	1,805	1,781	94%	90%
40	1,534	1,674	1,631	1,629	1,524	109%	99%
45	1,337	1,587	1,516	1,516	1,383	119%	103%
50	1,178	1,506	1,419	1,413	1,209	128%	103%
55	1,038	1,433	1,304	1,298	1,052	138%	101%
60	919	1,344	1,211	1,176	903	146%	98%
65	785	1,192	1,091	1,057	818	152%	104%
70	670	929	850	844	772	139%	115%
75	609	731	686	686	708	120%	116%
80	549	606	560	560	625	110%	114%
85	468	474	489	489	526	101%	112%
90	397	392	437	437	416	99%	105%
95	285	348	373	362	297	122%	104%
99	100	263	268	264	112	264%	113%

Table 16: Low-flow exceedance data for the Ovens River at Rocky Point (ML/week), 1980-1993

Flow Exceedance (percentile)	Natural	Current	Full Entitlement	Full + 5GL	Gauged	Current v Natural	Gauged v Natural
1	45,680	45,697	45,697	45,697	48,598	100%	106%
5	25,088	23,840	23,836	23,836	27,573	95%	110%
10	18,435	17,186	17,185	17,185	18,641	93%	101%
15	14,475	13,616	13,614	13,615	13,182	94%	91%
20	11,802	10,965	10,955	10,955	10,745	93%	91%
25	10,329	9,684	9,660	9,660	9,241	94%	89%
30	8,528	8,158	8,142	8,142	7,908	96%	93%
35	7,384	7,109	7,078	7,078	6,564	96%	89%
40	5,997	6,178	6,101	6,097	5,678	103%	95%
45	5,155	5,203	5,132	5,099	4,873	101%	95%
50	4,459	4,824	4,745	4,742	4,305	108%	97%
55	4,041	4,410	4,312	4,230	3,955	109%	98%
60	3,529	3,987	3,868	3,787	3,373	113%	96%
65	3,026	3,585	3,519	3,372	2,946	118%	97%
70	2,784	3,261	3,154	3,048	2,723	117%	98%
75	2,303	3,034	2,935	2,808	2,409	132%	105%
80	1,958	2,662	2,458	2,322	2,133	136%	109%
85	1,661	2,030	1,847	1,793	1,779	122%	107%
90	1,398	1,436	1,442	1,648	1,481	103%	106%
95	1,079	1,271	1,329	1,481	1,078	118%	100%
99	691	866	892	875	705	125%	102%

Table 17: Low-flow exceedance data for the Ovens River at Mulwala (ML/week), 1980-1993

	Natural	Current	Full Entitlement	Full + 5GL	Gauged	Current v Natural	Gauged v Natural
1	70,579	72,928	72,928	72,928	72,451	103%	103%
5	40,700	39,573	39,541	39,527	38,151	97%	94%
10	26,927	25,860	25,840	25,840	23,540	96%	87%
15	22,855	21,014	20,840	20,719	17,363	92%	76%
20	18,109	17,274	17,147	17,001	14,808	95%	82%
25	15,208	14,412	14,246	14,088	12,781	95%	84%
30	13,354	12,327	12,148	11,952	10,419	92%	78%
35	10,807	10,211	10,059	9,880	8,235	94%	76%
40	8,737	8,624	8,322	8,193	7,052	99%	81%
45	7,451	7,182	7,088	6,849	6,092	96%	82%
50	6,378	6,600	6,378	6,172	5,400	103%	85%
55	5,431	5,862	5,421	5,172	4,676	108%	86%
60	4,790	5,267	4,909	4,607	4,201	110%	88%
65	4,176	4,653	4,269	4,057	3,743	111%	90%
70	3,484	4,152	3,865	3,539	3,452	119%	99%
75	2,747	3,585	3,211	2,824	3,179	131%	116%
80	2,304	3,000	2,463	1,939	2,814	130%	122%
85	1,803	1,698	1,410	1,039	2,336	94%	130%
90	1,431	879	566	493	1,879	61%	131%
95	981	498	392	364	1,119	51%	114%
99	557	387	314	309	112	69%	20%

Appendix 2.5: Mean monthly flows

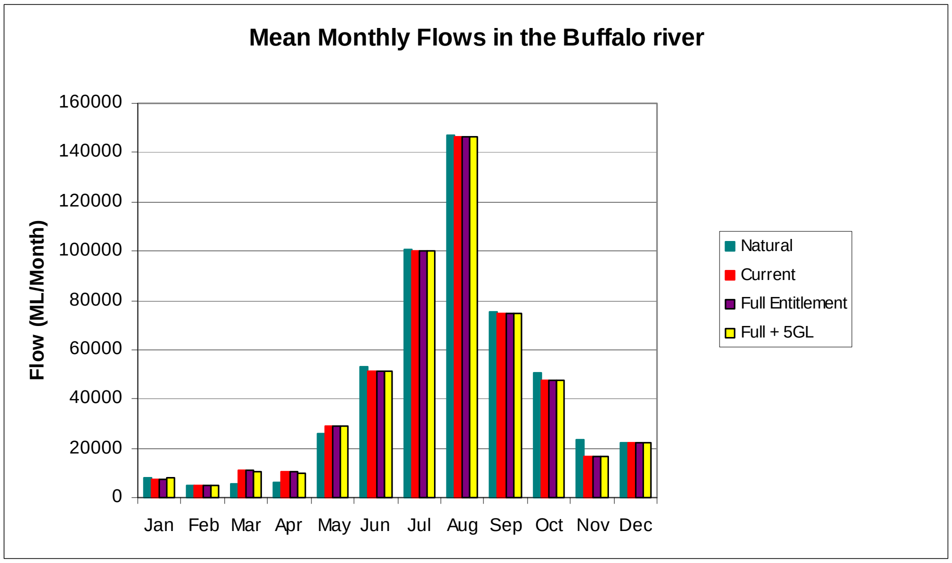


Figure 19: Mean monthly flows in the Buffalo River below Lake Buffalo (site 403220), January 1980 – June 1993.

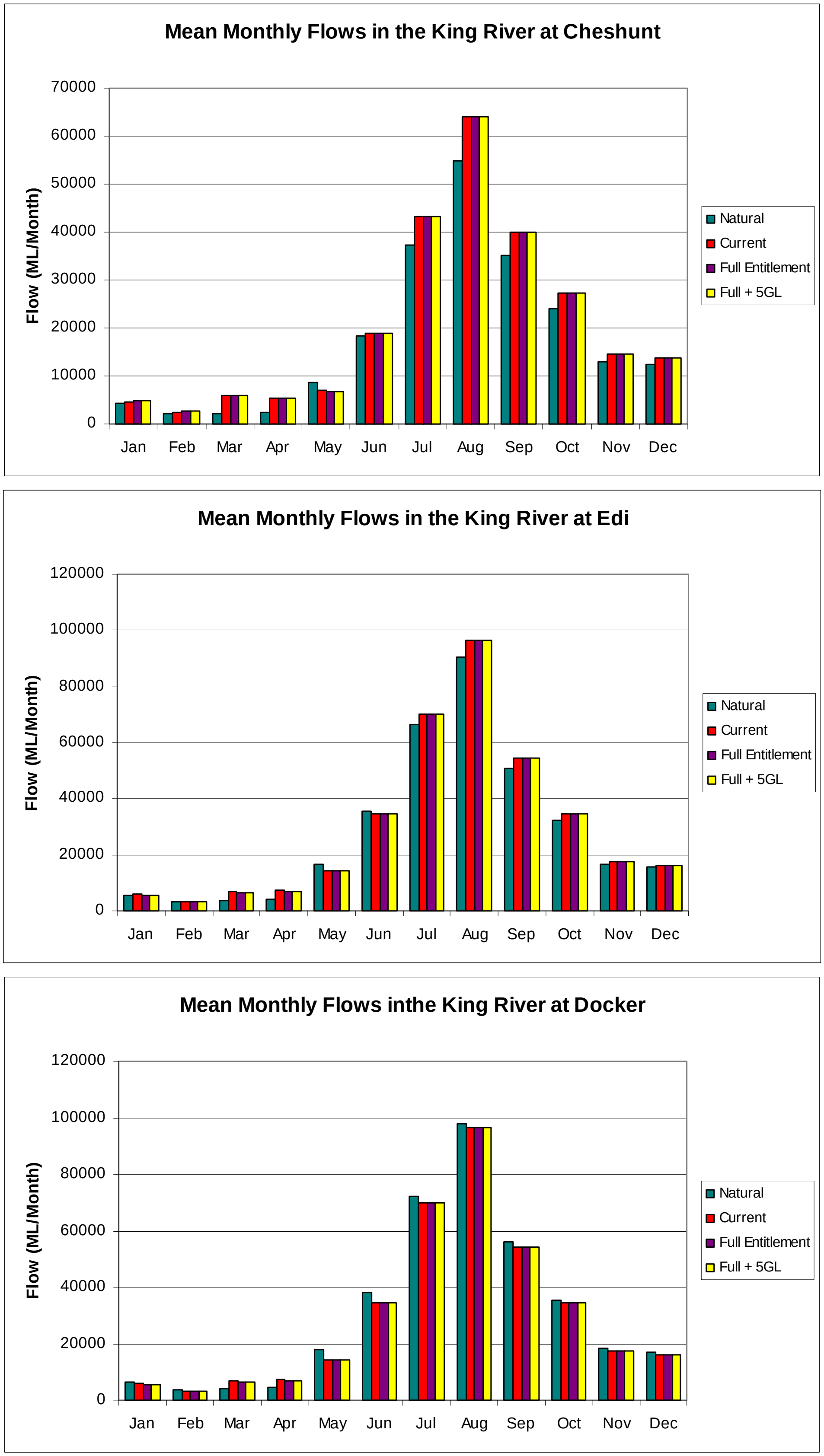


Figure 20: **Mean monthly flows in the King River at Cheshunt (site 403220), Edi (site 40340) and Docker (site 403223), January 1980 – June 1993.**

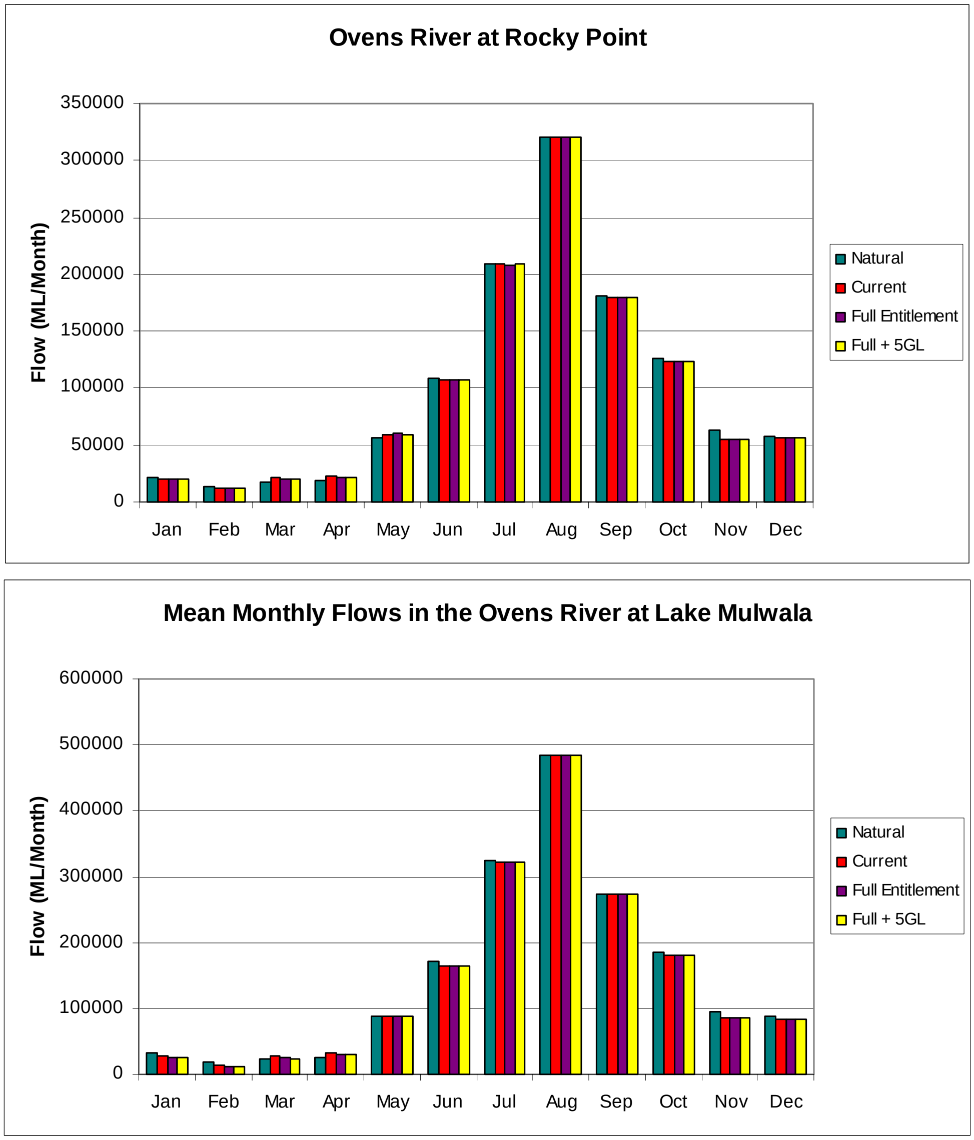


Figure 21: Mean monthly flows in the Ovens River at Rocky Point (site 403230) and at Lake Mulwala, January 1980 – June 1993.

APPENDIX 3 FISH DATA

Table 18: Freshwater fish species which have been found in the Ovens river. Information sourced from Department of Natural Resources and Environment Freshwater Fish database records. P= past record, S=stocked, T=translocated, A=anecdotal record.

	Reach 1	**Reach 2**	**Reaches 3 & 4**	**Reach 5**
	Buffalo River	**Ovens River between Buffalo River and King River**	**King River**	**Ovens River downstream of the King River**
Common Name				
Native species				
River Blackfish		▨	▨	▨
Two-spined Blackfish	▨	▨	▨	
Flat-headed Galaxias				▨
Mountain Galaxias		▨	▨	▨
Murray Cod	S	▨	▨	▨
Trout Cod	P,T	▨		P,S
Golden Perch		A	▨	▨
Macquarie Perch	P, T		▨	P
Silver perch				P
Sthn pigmy perch				▨
Australian Smelt		▨	▨	▨
Freshwater catfish				A
Western carp gudgeon		▨		▨
Crimson spotted Rainbowfish				▨
Unspecked hardyhead				▨
Introduced species				
Brown Trout	▨	▨	▨	▨
Rainbow Trout	▨	▨	▨	▨
Carp	▨	▨	▨	▨
Tench				P
Goldfish	▨	▨	▨	▨
Redfin, (English perch)	▨	▨	▨	▨
Gambusia	▨			▨
Oriental weather loach				▨

Table 19: Locations, years and approximate numbers of stockings of native fish species into the Ovens river.

Species	Locations	Years stocked	Total No. fish	No. of fish stocked in last 5 years
Murray cod	Buffalo R (D/S dam)	1987-91	104,200	0
Trout cod	Buffalo Ck.	1990-95	11,800	0
	Buffalo R	1992-95	3,306	0
	L. William Hovell	1985-86	5,000	0
	L. William Hovell	1987-91	314 (adult)	0
	Ovens R (Gapstead)	1997	13,100	13,100
	Ovens R (D/S Wang)	1998-00	139,530	139,530
Golden perch	Ovens R (D/S Everton)	1992-95	75,300	0
	Ovens R (D/S Wang)	1988-91	83,000	0
Macquarie perch	L. Buffalo	1981	50 (adult)	0
	L. Buffalo	1991	100 (adult)	0
	Buffalo R (U/S lake)	1984-93	155,823	0
	Buffalo R (D/S lake)	1987-91	104,200	0
Brown trout	Buffalo Ck	1907-58	3,308	0
	L. Buffalo	1978-91	1,329	0
	Buffalo R	1958-85	226,255	0
	Lake William Hovell	1980-91	1,438	0
	King R	1891-70	105,910	0
	Ovens R	1917-99	1,119,793	89,530
Rainbow trout	Buffalo Ck	1909-58	7,750	0
	L. Buffalo	1978-79	4,500	0
	Buffalo R	1930-79	79,263	0
	Lake William Hovell	1980-83	1,124	0
	King R	1911-78	308,910	0
	Ovens R	1917-78	724,360	0

Recorded Fish Kills

4/3/97 - Dead fish behind Wareena Park (One Mile Creek) South of Roy Street Bridge - Wangaratta - Expected source - stormwater flow off from industry.

11/3/98 -Stony Creek (Harrietville) is dry. Dead fish observed. Suspected source - trout farm drawing excess water from creek

14/01/99 - Dead fish 3 Mile creek - south Wangaratta - Suspected high temperature with low level of dissolved oxygen might have caused the fish kill. (Temp 24-27 degrees.)

15/01/99 - 50-60 dead fish in Buffalo Creek. People swimming had become sick. EPA when visiting site did not observe dead fish. Suspected source chemical drums from farmer close to creek holding up irrigation structure.

15/2/99 - Complainant observed dead fish 2-3 weeks ago in 3 Mile creek (Wangaratta). Discolouration of water. Suspected source- industry

7/11/99 - Dead fish in Dam that flows onto Happy Valley Creek. Source - believed to be spraying of nearby road with herbicide

24/11/99 - Dead fish in tributary stream of the Ovens River near Bright (Stackey Gully Road and Ovens Hwy). This was due to construction of culvert on the stream (with bad practice by the contractors)

9/6/00 - 28 kms from Whitfield on the road to Rose River. This was not a complaint about a fish kill as such, however the complainant indicated that there are almost no fish in the river. The complaint was about a bull dozer doing work in the river.

26/12/00 - Dead fish and dead ducks in creek at Bright. Complaint investigated by Parks Vic (Bright). Cause believed to be an insecticide dust (tomato dust) - container found on edge of creek.

Table 20: **Optimal spawning temperatures for fish species recorded in the Ovens River and its tributaries**

Species	Temperature (°C)
River Blackfish	16
Two-spined Blackfish	16
Mountain Galaxias	10
Murray Cod	20
Trout Cod	18
Golden Perch	23
Silver perch	23
Australian Smelt	15
Brown Trout	10
Rainbow Trout	10
Carp	17
Goldfish	17
Redfin, (English perch)	12

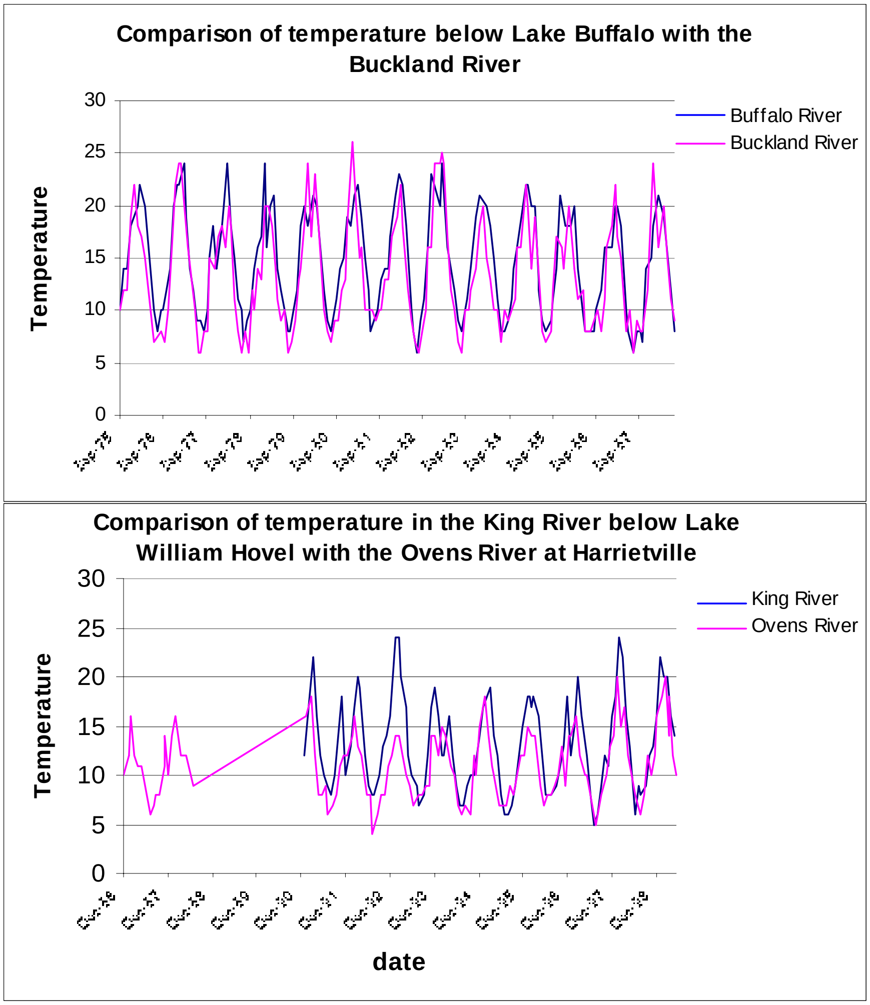


Figure 22: **Comparison of stream temperature below the dams with that in nearby river systems**

APPENDIX 4: MACROINVERTEBRATE FAMILIES FOUND IN STREAMS IN THE OVENS CATCHMENT FROM EPA BIOLOGICAL MONITORING.

EPA bugcode	name
IB01	Hydridae
IF61	Dugesiidae
IF99	Turbellaria
IH01	Tetrastemmatidae
IJ01	Gordiidae
IJ99	Nematomorpha
KG05	Lymnaeidae
KG06	Ancylidae
KG07	Planorbidae
KG08	Physidae
KG09	Glacidorbidae
KP02	Corbiculidae
KP03	Sphaeridae
LH01	Glossiphoniidae
LH99	Hirudinea
LO99	Oligochaeta
MM99	Mites
OP03	Eusiridae
OP06	Paramelitidae
OR05	Phreatoicidae
OR99	Isopoda
OT01	Atyidae
OT02	Palaemonidae
OV01	Parastacidae
QC05	Carabidae
QC06	Haliplidae
QC09	Dytiscidae
QC10	Gyrinidae
QC11	Hydrophilidae
QC13	Hydraenidae
QC20	Scirtidae
QC34	Elmidae
QC37	Psephenidae
QC39	Ptilodactylidae
QCAO	Hydrochidae
QD01	Tipulidae
QD04	Blephariceridae
QD06	Dixidae
QD07	Culicidae
QD09	Ceratopogonidae
QD10	Simuliidae
QD11	Thaumaleidae
QD12	Psychodidae
QD22	Athericidae
QD23	Tabanidae
QD24	Stratiomyidae
QD35	Empididae
QD36	Dolichopodidae
QD45	Sciomyzidae
QDAA	Aphroteniinae
QDAB	Diamesinae
QDAD	Podonominae
QDAE	Tanypodinae
QDAF	Orthocladiinae
QDAG	Pseudochironomini
QDAH	Tanytarsini
QDAI	Chironomini
QDAJ	Chironominae
QDZZ	Diptera (Larva)
QE02	Baetidae
QE03	Oniscigastridae
QE04	Ameletopsidae
QE05	Coloburiscidae
QE06	Leptophlebiidae
QE08	Caenidae
QH52	Mesoveliidae
QH54	Hydrometridae
QH56	Veliidae
QH57	Gerridae
QH61	Nepidae
QH62	Belostomatidae
QH63	Ochteridae
QH64	Gelastocoridae
QH65	Corixidae
QH66	Naucoridae
QH67	Notonectidae
QH68	Pleidae
QK01	Nannochoristidae
QL01	Pyralidae
QM01	Corydalidae
QM02	Sialidae
QN04	Neurorthidae
QO02	Coenagrionidae
QO04	Protoneuridae
QO05	Lestidae
QO07	Megapodagrionidae
QO08	Synlestidae
QO09	Amphipterygidae
QO12	Aeshnidae
QO13	Gomphidae
QO16	Corduliidae
QO17	Libellulidae
QP01	Eustheniidae
QP02	Austroperlidae
QP03	Gripopterygidae
QP04	Notonemouridae
QT01	Hydrobiosidae
QT02	Glossosomatidae
QT03	Hydroptilidae
QT04	Philopotamidae
QT06	Hydropsychidae
QT07	Polycentropodidae
QT08	Ecnomidae
QT10	Limnephilidae
QT13	Tasimiidae
QT15	Conoesucidae
QT17	Helicopsychidae
QT18	Calocidae
QT19	Helicophidae
QT21	Philorheithridae
QT22	Odontoceridae
QT23	Atriplectididae
QT24	Calamoceratidae
QT25	Leptoceridae

APPENDIX 5 EXPERIENCE OF THE OVENS SCIENTIFIC PANEL

The Scientific Panel established for this project is listed in Table 21. The team combines expertise in:

- Hydrology and geomorphology;
- Macroinvertebrate community ecology;
- Fish biology and ecology;
- Macrophyte, riparian and wetland ecology;
- Water quality; and
- River operations.

Table 21: Ovens Scientific Panel

	Organisation
Terry Hillman	CRC for Freshwater Ecology (Chairperson)
Barry Hart	CRC for Freshwater Ecology
John Koehn	CRC for Freshwater Ecology
Leon Metzeling	Environment Protection Authority
Ian Rutherfurd	CRC for Catchment Hydrology
Graham Hannan	Goulburn Murray Water
Jane Roberts	CSIRO
Peter Cottingham	CRC for Freshwater Ecology (Project Manager)

Dr Terry Hilllman chaired the Scientific Panel and led it through its deliberations. The Scientific Panel will was supported by Peter Cottingham, who served as Project Manager to coordinate Panel activities and liaise with DNRE and the Bulk Water Project Group. A brief description of the experience and skills of the Scientific Panel is presented below.

Dr Terry Hillman is the Director of the Murray Darling Freshwater Research Centre and Deputy Director of the CRC for Freshwater Ecology, in which he has also been leader of the Floodplain and Wetland Ecology program. Terry has over 35 years experience as a researcher providing advice on the management of inland waters, especially floodplain wetlands. Investigations of wetlands on the lower Ovens River have formed a key part of Terry's research on river-floodplain interactions. Terry's many activities include serving on subcommittees related to water quality and biological monitoring for the Murray Darling Basin Commission, as a member of an expert panel examining ecological responses to flow management along the River Murray, as a Board Member of the North-East Catchment Management Authority, and as Chair of the Scientific Expert Panel on ecological flows for the Barling-Darling River. Together with John Whittington, Terry authored the CRCFE report' Sustainable Rivers: The Cap and Environmental Flows' as a communication document explaining the importance of the Cap in maintaining river health in the Murray Darling Basin. Terry has recently secured funding for rehabilitation work in the Kiewa River catchment through the Natural Heritage Trust.

Dr John Koehn is an aquatic biologist specialising in all aspects of the ecology of freshwater native fish. John has over 16 years experience in research, assessment, conservation and management of freshwater ecosystems and is the author of over 50 publications. He has gained an international reputation for his research and is a key player in providing biological information and management advice. He has been active in assessing the conservation status and threats to many endangered species as well as preparing and implementing action statements and management plans for them. This has been reflected in his inclusion on ministerial committees, national recovery teams and project steering committees. John has recently been recognised for his contribution to the conservation of native freshwater fish by being awarded the 1997 Gold Banksia Award, one of the most prestigious environmental awards in Australia. John has experience in managing large multi disciplinary project teams and is always keen to provide an innovative approach to problem solving and providing realistic management solutions. In particular, John has studied the native fish communities of the Ovens River for many years and has developed management plans for key species such as Murray cod, trout cod, silver perch and catfish.

Dr Leon Metzeling is a Senior Ecologist in the Catchment and Marine Studies group of the Victorian Environment Protection Authority. Leon is also a research scientist in the Cooperative Research Centre for Freshwater Ecology, working on projects related to long-term variability of benthic invertebrate communities, statewide monitoring using AUSRIVAS, and the taxonomic resolution required for monitoring purposes water quality and river health. Leon’s EPA activities have included investigations of salinity, fish farming, metal contamination of lakes and streams, biological monitoring and urban lake ecology. He has also prepared expert witness statements for prosecutions and advice on policy issues. Leon has played a leading role in monitoring the health of rivers across the Ovens catchment as part of statewide initiatives.

Dr Ian Rutherfurd has 15 years experience working on the geomorphology and management of streams, including those in the Ovens catchment. Following a Fullbright Fellowship in the USA, Ian spent several years as a consultant fluvial geomorphologist before becoming a project leader (and senior research fellow) in the Cooperative Research Centre for Catchment Hydrology. Over the last five years he has managed the waterway management and rehabilitation project, producing five PhD students, and completing several large research contracts. His work has turned increasingly to the restoration of disturbed fluvial systems, with a special emphasis on the hydraulic, hydrological and geomorphic aspects of stream rehabilitation. He has recently completed a national manual of stream rehabilitation under contract to LWRRDC. In addition, Ian has served on numerous expert panels and committees related to river and catchment management, and as an invited speaker to several conferences.

Graeme Hannan is the Production Manager at Goulburn Murray Water, which he has represented in a range of state and national forums. Graeme’s project work has included flood studies and drainage design projects requiring a significant degree of consultation with the affected public. It has also included water resource evaluation, water quality management, master planning and detailed design of water supply, sewerage and drainage infrastructure for large development projects in Australia, Indonesia, Malaysia and Papua New Guinea. Graeme’s previous experience included preparation of master plans and numeric modelling for a variety of flood and drainage studies, and design work for water supply, drainage and wastewater projects. He has international experience in office and project management and in urban infrastructure development for appraisal for multi-lateral funding and recent experience in water resource management, bulk water supply system operations, modelling and business impact analysis of water reform proposals.

Dr Jane Roberts is an ecologist, specialising in plants and water regime of riverine and associated aquatic habitats, with 10 years research and practical experience of lowland rivers and wetlands of the Murray-Darling Basin. Her technical knowledge of ecology, growth and life history covers a number of plant species and communities and includes different growth forms, such as woody and non-woody as well as aquatic and semi-terrestrial plant species. This technical knowledge is for rivers, wetlands and floodplains, and covers highly modified and constructed habitats such as regulated rivers, storages, drains, irrigation systems, dams and evaporation basins. She has a good knowledge of key widespread problem or nuisance species within these environments, and has experience in assessing impacts, evaluating controls and working towards minimising ecological or production costs. She believes that understanding the present and working towards the future also requires reaching back into the past, hence her interest in environmental history where she has pioneered the scientific use of 'soft' information such as oral history in relation to a lowland river. Ten years field and regional experience in inland south-eastern Australia has made her familiar with ecological issues resulting from development and use of natural water resources for irrigated agriculture and domestic use. As a research scientist, she has lead and participated in applied scientific research in a range of aspects of water management (river, tailwater, water regime, drainage) and their environmental consequences, often within the context of the Murray-Darling Basin.

Peter Cottingham joined the CRC Freshwater Ecology in a technology transfer and consultant role. Peter has been responsible for preparing major technology exchange strategies and plans for the various CRCFE programs and projects. Peter's position is the first application of the 'knowledge broker' concept developed by the CRCFE to facilitate knowledge exchange between environmental researchers and the end-users of the knowledge generated by the CRCFE. In this role he has also led a number of consulting projects focussed on future investigations and the management of inland water resources, one of which was the *Riverine Management and Rehabilitation Scoping Study* undertaken for the MDBC. Peter was also involved in a CRCFE project that identified interim environmental flows for the Thomson and Macalister Rivers in Gippsland, and in the review of the ecological sustainability of the Cap on diversions in the Murray Darling Basin, and the review of performance monitoring of environmental flows proposed for the Woronora River, NSW. Prior to this, he had accumulated 14 years experience as an environmental consultant and researcher of inland and coastal waters. Peters' research has focused on the effectiveness of using constructed wetlands for the treatment of wastewater. In recent years, his work has focussed on the development of catchment based nutrient management strategies and water quality investigations of rivers, lakes and wetlands.