Goulburn Campaspe Loddon Environmental Flow Delivery Constraints Study

FINAL REPORT

- Final 1
- 23 November 2006

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Executive Summary

E1 Overview

For most of the regulated rivers in the Goulburn, Campaspe and Loddon catchments, flow regimes have been determined that would meet basic river health objectives. Some elements of these flow regimes have been implemented, while others require water resources that are currently not available. In addition, the Living Murray Program also expects to require release of water from Victorian tributaries to meet River Murray environmental flow needs. Governments have been actively working to provide additional water for a range of environmental flow needs. However, in addition to the lack of available environmental water, there are other constraints to providing the proposed environmental flow regimes. So a study was needed to scope the extent of these constraints and possible options for reducing or eliminating them.

In April 2006, Sinclair Knight Merz (SKM) was commissioned by the Goulburn Broken Catchment Management Authority (GBCMA) to undertake an investigation into the constraints to delivery of environmental flows in the Goulburn, Campaspe and Loddon catchments. The aim of the study is: *"To implement the effective delivery of the Environmental Water Reserve (EWR) for the Goulburn, Campaspe and Loddon River systems and the River Murray to maximise ecology outcomes. This will be achieved by:*

- *assessing the structural and operational constraints to provision of desirable environmental flows in the Goulburn, Campaspe and Loddon River systems including the delivery of water towards the Living Murray Program; and*
- *developing prioritised options for operational and structural changes to the existing infrastructure most likely to enhance ecological outcomes."*

The Study Area comprises the Goulburn River from Lake Eildon to the junction with the River Murray, Broken Creek, the Campaspe River from Lake Eppalock to the junction with the River Murray, the Coliban River from Malmsbury Reservoir to Lake Eppalock, the Loddon River from Cairn Curran Reservoir to the junction with the River Murray, Tullaroop Creek from Tullaroop Reservoir to the Loddon River, and Birches Creek from Newlyn Reservoir to Tullaroop Reservoir.

This study has developed and coarsely assessed a large number of options. Significant further investigations would be required for most options to confirm details, particularly estimated costs, and to provide more detailed assessment of their effectiveness and impacts.

E.2 Environmental Flow Recommendations

Recommended environmental flow regimes for all of the Study Area's streams except Broken Creek have been established previously by Scientific Panels. The Steering Committee for the current study provided recommended environmental flow regimes for Broken Creek, and for the flow regimes to be delivered by the Study Area's streams as a contribution to the Living Murray Initiative.

Summer flows in the Goulburn River upstream of Goulburn Weir almost always significantly exceed the magnitude of flows required to provide for riffle habitat and shallow water habitat and are also typically below the minimum flow to provide for deep water habitat.

In all reaches of the Goulburn River, the frequency of overbank events is less than natural and less than recommended. However flow events of the magnitude required to fulfil Living Murray requirements are frequently experienced.

The Steering Committee has specified minimum flows for Broken Creek for the purpose of keeping fish ladders open, to minimise Azolla accumulation and to manage dissolved oxygen. These minimum flows occur in the majority of days during the specified months. Fresh flows for flushing Broken Creek in response to rapid Azolla blooms occur in nearly 90% of years, but it is not known whether fresh flows occur at the same time as Azolla blooms.

There is a significant flow inversion in the Campaspe River downstream of Lake Eppalock, Loddon River between Cairn Curran Reservoir and Loddon Weir and downstream of Kerang Weir, and Tullaroop Creek downstream of Tullaroop Reservoir, with water being harvested in the winter months and released in the summer for irrigation supply. In most cases, river regulation has removed the natural flow variation from the system. Often the summer and winter fresh volumes are being met but the recommended number and duration are not.

E.3 Constraints to Delivery of Recommended Environmental Flow Regimes

The constraint to the delivery of the recommended summer environmental flow regime that would be most difficult to overcome is a need to deliver peak irrigation demands, in summer, via some reaches of the streams in question. This applies to the Goulburn River between Eildon and Goulburn Weir, the Campaspe River downstream of Lake Eppalock, the Loddon River between Cairn Curran Reservoir and Loddon Weir and downstream of Kerang Weir, and Tullaroop Creek downstream of Tullaroop Reservoir.

Delivery of recommended flows required for management of Azolla in Broken Creek is predominantly constrained by a lack of available channel capacity to deliver these flows during the irrigation season.

Lack of available reservoir outlet capacity would constrain delivery of some of the recommended high flow components to the Coliban River downstream of Malmsbury Reservoir, the Campaspe River downstream of Lake Eppalock, Birches and Tullaroop Creeks between Newlyn and Tullaroop Reservoirs, and Tullaroop Creek downstream of Tullaroop Reservoir.

Delivery of recommended high flows would also be constrained by the potential to exacerbate flooding along the upper Goulburn, particularly around Thornton and Molesworth, and along the Coliban River around Malmsbury. Flooding is unlikely to be a significant constraint to environmental flow delivery in other reaches.

E.4 Options to Deliver Flow Regimes

A range of options have been developed, where required, to improve the delivery of each recommended environmental flow component in each reach. The effectiveness of each of these options in delivering all environmental flow components across all reaches in the system in which the options apply has been assessed. Each option has then also been assessed in terms of feasibility, robustness, confidence associated with its scoping and evaluation, and secondary impacts and consequences. In developing options, it has generally been assumed that the volume of water required to provide the recommended environmental flow regime is available in storage.

In reaches where delivery of the recommended summer flow regime is constrained by the need to deliver peak irrigation demands, the types of options that have been considered have generally comprised pipelines or channels to convey peak irrigation flows, on-farm or regional winter fill storages, supply of peak irrigation demands from other available sources, and pulsing of flows to provide some summer variability. In reaches where delivery of high flow components is constrained by lack of available reservoir outlet capacity, options considered have included modifications to outlet works, modified operation including piggybacking on high downstream tributary inflows, and construction of downstream pondages with high capacity outlet works.

In general, the study found:

- there are no constraints to providing many environmental flow elements;
- many constraints can be overcome at modest to no cost; and
- high summer flows are generally prohibitively expensive to overcome.

The major outcomes of this study have been the development of a range of potential options to deliver the recommended environmental flow regimes, and demonstration of a process for:

- assessing the effectiveness of these options in delivering the recommended flows;
- packaging options to deliver multiple flow components in multiple reaches of each system; and

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- assessing each option or package of options in terms of feasibility, robustness, confidence associated with scoping and evaluation, and secondary impacts and consequences.

Selection of options and packages of options for future implementation will depend on a large number of factors. Some of the more significant of these will include social impacts, availability of funding, availability of environmental water reserves, and political decisions about which systems and reaches should have the highest priorities for implementation of measures required to deliver the recommended flow regimes. It is also likely that the recommended environmental flow regimes will be refined over time, particularly in relation to the Living Murray Initiative.

Global factors such as climate change, catchment change and water trading, may also impact on option requirements and option assessment. Future refinement and selection of options and packages will need to take all these factors into account.

E.5 Further Investigations and Monitoring

The study has revealed a number of areas where improved information and knowledge would significantly improve the understanding of measures required to enhance delivery of the recommended environmental flows, and the confidence that options will deliver the recommended flows. These include:

- Transmission losses, particularly in long reaches of river where minimum summer low flows have been recommended, and the reaches in question do not carry high summer irrigation flows;
- Magnitude of breakaway and return flows in the middle reaches of the Loddon River for flows around bankfull level;
- Magnitude of attenuation of flood releases downstream of some of the major storages; and
- Flooding thresholds that might constrain delivery of recommended high flows to some reaches.

Improved gauging and monitoring to address these knowledge and information gaps has been recommended.

The study has also indicated a number of areas where the recommended environmental flows require refinement or clarification, and other areas where some of the flow recommendations are inconsistent with each other. The volumes associated with the recommended Living Murray Initiative contributions from streams within the study area, particularly in winter and spring, are substantial, and more work is needed to better clarify and detail these contributions.

1. Introduction and Background

1.1 Background

For most of the regulated rivers in the Goulburn, Campaspe and Loddon catchments, flow regimes have been determined that would meet basic river health objectives. Some elements of these flow regimes have been implemented, while others require water resources that are currently not available. In addition, the Living Murray Initiative also expects to require release of water from Victorian tributaries to meet the River Murray environmental flow needs.

Governments have been actively working to provide additional water for a range of environmental flow needs. In order to deliver environmental flows, two conditions must be achieved:

- **No constraints:** There are no physical or operational constraints on the delivery of the environmental flows; and
- **Water available:** Water is available to meet the environmental flow requirement.

The delivery of environmental flows requires a balance between both of these two conditions. For example, there is no benefit in augmenting a reservoir outlet in order to deliver recommended environmental flows if the water is not available for release. Equally, there is no benefit in having water available for environmental use if there are physical obstacles to releasing the water in a way that is consistent with the recommended flow regime.

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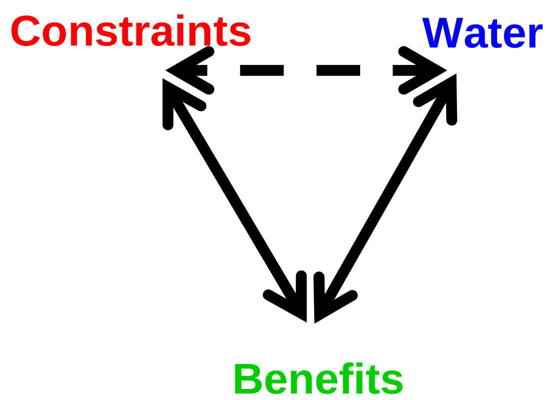
The primary objective of environmental flows is to achieve environmental benefit. Despite this, any activity exists within a social and economic context. The environmental benefit gained from the delivery of environmental flows (or individual flow components) must also be weighed against the social and economic costs. This requires analysis of the financial investment and secondary impacts associated with options to meet the two primary conditions.

Figure 1 shows the relationship between the two conditions required to deliver flows and environmental benefit.



- **Figure 1 The environmental flow delivery triangle**

Achieving the two conditions required to deliver environmental flows is to be staged in a multi-phased assessment reflecting each of the three arms shown in Figure 1. The steps involved in the identifying and prioritising options for the delivery of environmental flow recommendations are set out in Figure 2.

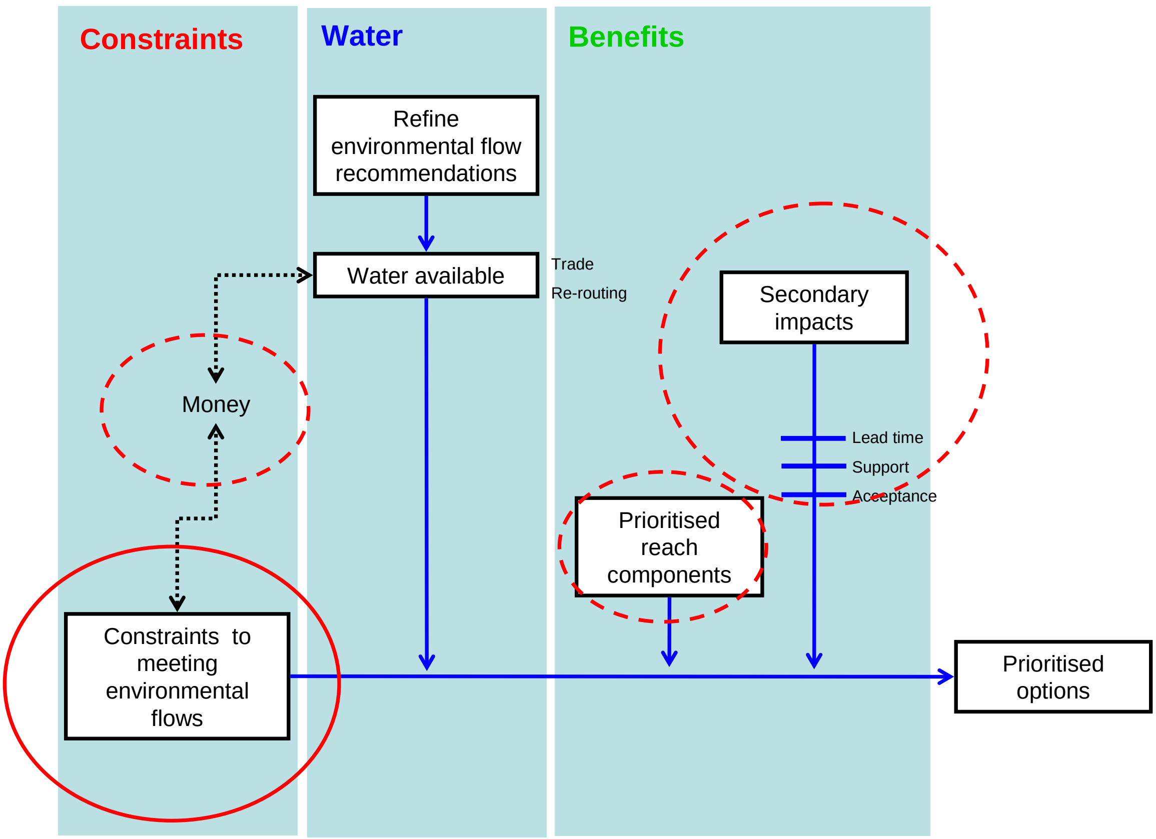


Figure 2 The steps involved in identifying and prioritising options for the delivery of environmental flow recommendations steps addressed in the current study are circled in red

The first phase in the process relates to achieving the first condition: the removal of physical and operational constraints. This step forms the basis of the current study which identifies physical and operational constraints and options to overcome these.

For the purposes of this study it has been assumed that water is available to meet the environmental flow requirements. Testing the validity of this assumption forms the second phase in the option identification and assessment process. This may involve refining environmental flow recommendations and modelling the volume and timing of releases in order to achieve conformance. Options to make additional water available and optimise the timing and volume of flows would be identified through this second stage.

The third arm in the assessment process involves weighing environmental benefit against other costs/ impacts associated with options. In the first instance, this involves understanding the environmental benefit. The assumption underpinning environmental flows is that the delivery of flows will achieve environmental benefit. In practice, however, the delivery of one flow component may achieve more environ75

mental benefit than the delivery of another flow component. As such it is important that reaches and components can be prioritised in order to maximise the environmental benefit gained. Having refined the understanding of environmental benefit it is necessary to identify cost associated with implementing options and potential secondary impacts. This study goes part of the way in making this assessment by looking at the costs and secondary impacts associated with options to overcome physical and operational constraints. In addition, it sets out a method for packaging options. Once options to address the water availability condition have been identified they will need to be subject to a similar assessment.

1.2 Overview

In April 2006, Sinclair Knight Merz (SKM) was commissioned by the Goulburn Broken Catchment Management Authority (GBCMA) to undertake an investigation into the constraints to delivery of environmental flows in the Goulburn, Campaspe and Loddon catchments. The study brief is reproduced as Appendix A.

The aim of the study, as stated in the Brief, is:

"To implement the effective delivery of the Environmental Water Reserve (EWR) for the Goulburn, Campaspe and Loddon River systems and the River Murray to maximise ecology outcomes.

This will be achieved by:

- *assessing the structural and operational constraints to provision of desirable environmental flows in the Goulburn, Campaspe and Loddon River systems including the delivery of water towards the Living Murray Program; and*
- *developing prioritised options for operational and structural changes to the existing infrastructure most likely to enhance ecological outcomes."*

The Study Area comprises:

- *"the Goulburn River (including the floodplain) from Lake Eildon to the junction with the River Murray, irrigation channels diverting water from Goulburn Weir, and Broken Creek;*

- *the Campaspe River (including the floodplain) from Lake Eppalock to the junction with the River Murray, irrigation channels and pumps diverting water from and into the Campaspe River, and the Coliban River from Malmsbury Reservoir to Lake Eppalock;*
- *the Loddon River (including the floodplain) from Cairn Curran Reservoir to the junction with the River Murray, irrigation channels diverting water from and into the Loddon River, the Tullaroop Creek from Tullaroop Reservoir to the Loddon River, and Birches Creek from Newlyn Reservoir to Tullaroop Reservoir."*

The study is being conducted under the direction of a Steering Committee comprising representatives from the GBCMA, the Department of Sustainability and Environment (DSE), Goulburn-Murray Water (G-MW), the Murray Darling Basin Commission (MDBC), and the North Central Catchment Management Authority (NCCMA). Steering Committee members are listed in Appendix B.

This study has been undertaken with funding from the Murray-Darling Basin Commission, Goulburn-Murray Water and the Victorian Department of Sustainability and Environment.

1.3 Options Development Workshops

Options for enhanced delivery of environmental flows in the Goulburn/Broken catchment were discussed at a workshop with Steering Committee members and other stakeholders in Shepparton on 31 May 2006. A similar workshop on options in the Campaspe and Loddon catchments was held in Huntly on 5 July 2006. The agendas for both workshops included environmental flow recommendations, current conformance with those recommendations, reasons for any non-conformance, constraints associated with delivery of recommended environmental flows, and potential options for overcoming environmental flow delivery constraints.

1.4 Report Structure

An overview of the Study Area's supply systems is provided in Chapter 2. Environmental flow recommendations for each of the Study Area's streams, and the current extent of conformance with these recommendations are presented in Chapter 3. Constraints to the delivery of the recommended environmental flows, and options to overcome these constraints are summarised in Chapter 4 (Goulburn/Broken),Chapter 5 (Campaspe), 6 (Birches and Tullaroop Creeks) and 7 (Loddon), with further details of options presented in Appendix G to Appendix K. The development and assessment of packages of individual options are presented in Chapters 8 and 9. Knowledge and Information Gaps are discussed in Chapter 10, and conclusions and recommendations are presented in Chapter 11.

2. The Study Area

2.1 Goulburn River System

2.1.1 Overview

Lake Eildon and Waranga Basin are the major storages for the supply to the Shepparton, Central Goulburn, Rochester and Pyramid-Boort Irrigation areas, diverters in the Goulburn River and Lower Broken Creek. The study area is shown in Figure 3 There is also a volume of water held in Eildon to account for the net trade out of the Goulburn System and the water savings realised in Snowy and Murray Systems. This resource can be transferred to the River Murray.

2.1.2 Goulburn Entitlements

Current irrigation entitlements in the Goulburn System total around 975 GL with an irrigated area of 360,000 ha. Irrigation areas in the Goulburn System stretch from the Shepparton Irrigation Area in the east across to the Pyramid-Boort Irrigation Area which is in part to the west of the Loddon River. Table 1 gives the breakdown of irrigated area and entitlement for the major irrigation areas in the Goulburn System. In 2004/2005 the final seasonal allocation for Goulburn irrigators was 100% with a resultant usage of 997 GL.

- **Table 1 Goulburn System Irrigation (Goulburn-Murray Water, 2005)**

Irrigation Area	Irrigated Area (ha)	Entitlement (GL[(1)])
Shepparton	51,000	174
Central Goulburn	113,100	373
Rochester	61,700	162
Pyramid-Hill Boort	126,400	218
Goulburn Diverters	7,753	48
Total Goulburn	360,000	975

(1) From G-MW Annual Report

2.1.3 Lake Eildon

Lake Eildon was completed in 1955 to meet increasing demand for irrigation water in the Goulburn Valley. It has a catchment area of around 3,900 km^2 with major tributary streams of the Goulburn River flowing into the storage including the Delatite, Howqua, Jamieson and Big Rivers. At its full supply level of 288.90 mAHD, Lake Eildon holds 3,390,000 ML with a water surface covering an area of 13,840 hectares.

Outlet works at Lake Eildon comprise a hydropower station, a low level outlet valve, two spillway valves and three spillway flood gates. The hydropower station operated by AGL Hydro, is comprised of 4 turbines, 2 of 60 MW capacity and 2 of 75 MW capacity, and is the primary method for the regulated release of water. Table 2 details the maximum discharge at full supply level and the operating ranges of the various outlet works. Discharge capacity of Lake Eildon at various levels is summarised in Table 3.

- **Table 2 Lake Eildon Outlet Works: Discharge Capacities and Operating Ranges**

Outlet	Discharge Capacity at FSL (ML/d)	Operating Range	
		Minimum mAHD(%Capacity)	Maximum mAHD(%Capacity)
Low Level Irrigation Outlet	8,600	237.09 (2.7)	288.90 (FSL)
Turbines 1&2	-	248.00 (9.1)	263.00 (27.9)
Turbines 3&4	16,150	248.0 (9.1)	288.90 (FSL)
Spillway Gates (3 No.)	157,000	282.81 (77.4)	288.90 (FSL)
Spillway Valves (2 No.)	5,500 each	255.30 (16.6)	288.90 (FSL)

- **Table 3 Lake Eildon Discharge Capacity**

Storage Capacity (%)	Storage Volume(ML)	Storage Level (m)	Discharge Capacity (ML/d)
10%	338,790	248.90	20,500
16.6%	562,391	255.30	20,300
20%	677,580	257.80	23,600
30%	1,016,370	264.20	24,500
40%	1,355,160	269.20	23,400
50%	1,693,950	273.50	25,000
60%	2,032,740	277.20	26,300
70%	2,371,530	280.50	27,450
77.4%	2,622,235	282.81	28,200
80%	2,710,320	283.60	34,330
90%	3,049,110	286.30	92,835
100%	3,387,900	288.90	183,930

G-MW's order will be based on the maximum of the required inflows into Goulburn Weir or the minimum flow requirements prescribed in the Goulburn-Murray Water (Lake Eildon to Goulburn Weir) Conversion Order 1995.

Flood operations are based on target filling curves. High inflows may result in the target curve being temporarily exceeded and controlled releases will then aim to bring the storage back to target. If there is insufficient airspace to absorb a flood peak then releases downstream may need to be increased above downstream channel capacities resulting in flooding.

When the reservoir is at FSL G-MW has the option of allowing the reservoir to surcharge by up to 600 mm during a flood event. This operational situation is aimed purely at flood mitigation and in the 1993 flood event resulted in reducing the flood peak immediately downstream of Eildon by more than 80,000 ML/day. Surcharging of the reservoir has occurred numerous times to a much lesser extent in the past, typically reducing flow peaks downstream by the order of 3,000 to 10,000 ML/day.

If flow peaks in excess of around 40,000 ML/day in the Goulburn downstream of Eildon then assets in the Township of Thornton will be affected by floodwaters.

2.1.4 Goulburn Weir

Goulburn Weir is a concrete and masonry structure that provides a sufficient water level to allow diversions to the Stuart-Murray Canal, Cattanach Canal and the East Goulburn Main Channel. Releases to the Goulburn River downstream of the Weir are made via 9 radial gates and 2 overshot gates that are operated in large floods. The gates are capable of releasing low flows in the range of 100 ML/d to over 1,000 ML/d as well as the higher flows when Goulburn Weir is spilling.

At its full supply level of 124.24 mAHD there is a pool of 25,000 ML and a surface area of 1,130 hectares is formed. The weir is required to be operated close to its FSL to allow maximum diversion into the Stuart-Murray Canal, Cattanach Canal and the East Goulburn Main Channel. Hence, the storage cannot be drawn down to take advantage of any significant unregulated inflows and these flows must be passed downstream.

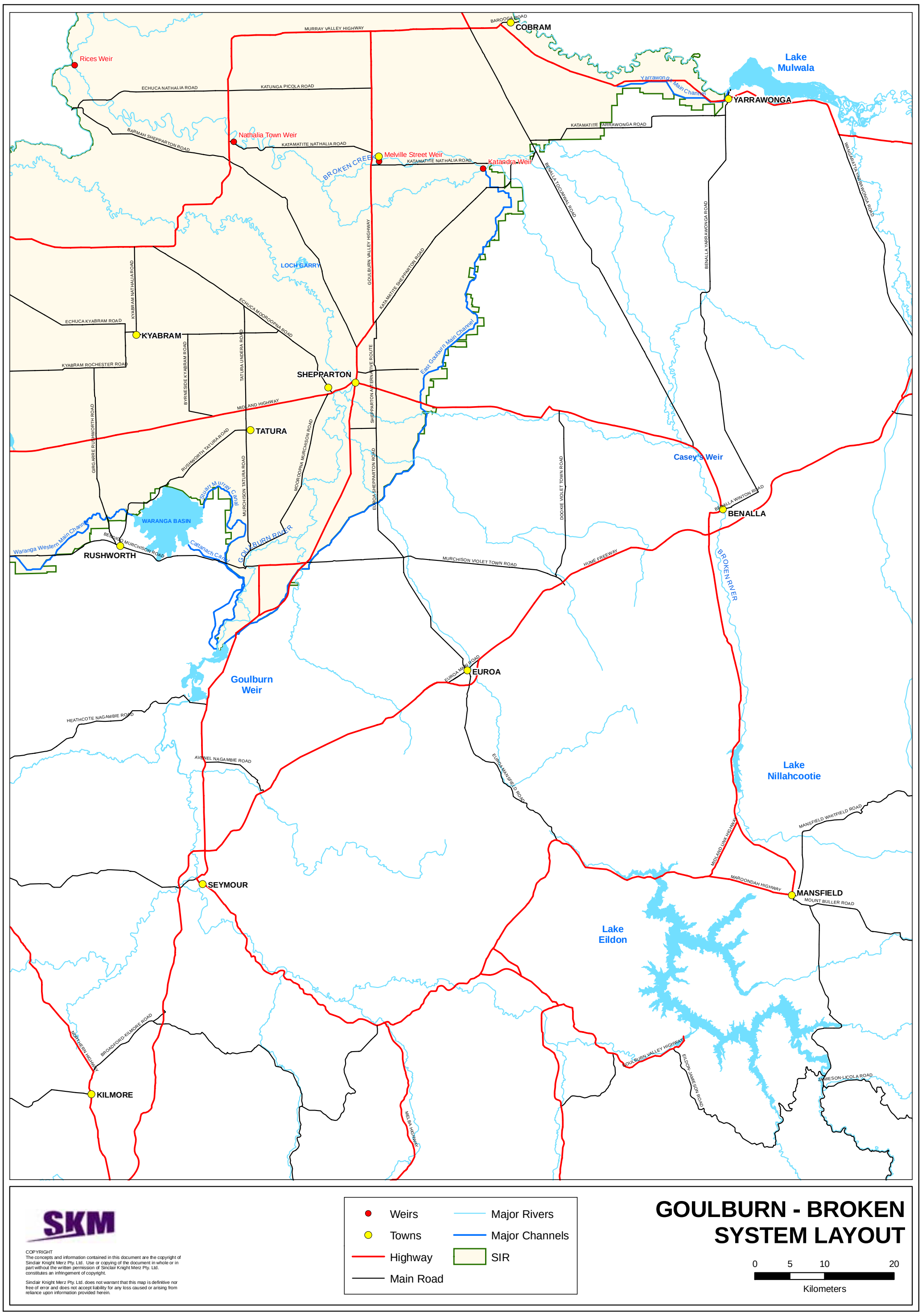
2.1.5 East Goulburn Main Channel

The East Goulburn Main (EGM) Channel is the main supply channel for the Shepparton Irrigation Area. From Goulburn Weir it runs 95 km to the Broken Creek, outfalling at Katandra Weir. Up to 40,000 ML of regulated outfall to supply diverters in the lower Broken Creek can be made each year. The EGM's offtake capacity at Lake Nagambie is 2,590 ML/d with capacity having reduced to around 300 ML/d at its outfall to the Broken Creek. During periods of peak demand there is negligible spare capacity in the EGM.

2.1.6 Stuart Murray Canal

Diversions to the Stuart-Murray Canal are either passed through to the Waranga Basin or diverted into the Central Goulburn Area via the 1,2,3,4 and 6 offtakes. The capacity of the Stuart Murray Canal at the Goulburn Weir offtake regulator is 3,500 ML/d. The available capacity reduces once Waranga Basin's volume climbs above 380,000 ML. At close to full supply the volume that can be passed into Waranga Basin falls to 2,000 ML/d.

Current operations restrict the maximum regulation to the Stuart-Murray Canal to a change of ±400 ML/d with 3 regulations/day. In an emergency, four regulations/day can be undertaken.



▪ **Figure 3 Goulburn Broken System Layout**

2.1.7 Cattanach Canal

The Cattanach Canal can divert up to 3,690 ML/d to Waranga Basin from Goulburn Weir. No irrigation diversions occur along the channels length. In general flows in the Cattanach Canal will be varied in preference to the Stuart-Murray Canal resulting in it being operated to pass Goulburn Weir inflow variations into Waranga Basin.

As with the Stuart-Murray Canal the maximum regulation change is ±400 ML/d, however the number of regulations in a day is not restricted.

2.1.8 Waranga Basin

Waranga Basin is an off-stream storage that enables unregulated flows into Goulburn Weir to be harvested and provides a balancing resource for the operation of the Goulburn System. Waranga Basin holds 412,000 ML at its full supply level of 121.36 mAHD.

Waranga Basin has two outlets, the minor outlet which supplies the Central Goulburn 7 and 8 systems at up to 1,850 ML/d and the major outlet which supplies the Waranga Western Channel at rates of up to 4,210 ML/d. The Central Goulburn 9 offtake from the Waranga Western Channel is a small distance downstream of the Major Outlet and the WWC capacity reduces to 3,350 ML/d below this point

Waranga Basin operations are based on maximising harvesting of unregulated flows between Eildon and Goulburn Weir and its local catchment during the winter spring period, maintaining sufficient resource to supply irrigation demands during the summer and early autumn and then maximising available airspace at the end of the irrigation season for future harvesting operations. Waranga Basin is initially filled to 300mm below FSL to limit erosion damage to the embankment. The time at FSL is minimised by filling the storage just prior to when irrigation demands are expected to exceed harvested inflows.

2.1.9 Lower Goulburn River

Under the current Bulk Entitlement (BE) there is a minimum flow requirement in the Goulburn River immediately downstream of Goulburn Weir of a weekly average flow of 250 ML/d and minimum flow on any one day of 200 ML/d. Releases from Goulburn Weir may also be driven by the need to meet minimum flow requirements when there are low tributary inflows and no other passing flow requirement at McCoys Bridge. Passing flow requirements at McCoys Bridge are:

(i) average monthly minimum of 350 ML/d for the months of November to June inclusive, at a daily rate of no less than 300 ML/d; and

(ii) average monthly minimum of 400 ML/d for the months of July to October inclusive, at a daily rate of no less than 350 ML/d.

The Goulburn River downstream of Shepparton is confined within a leveed floodway but its capacity is inadequate to convey moderate flood events. Downstream of Loch Garry the capacity is only sufficient to pass a 7 year ARI event and at the Yambuna Choke only 2 year ARI event can be conveyed. To lessen the flows being passed in the leveed floodway a number of outlets allow flows to enter the floodplain.

The highest capacity outlet is the 48 bay Loch Garry regulator which can pass up to 60,000 ML/d from the floodway into Bunbartha Creek. Operation of Loch Garry is based on Shepparton river heights. Removal of bars commences 24 hours after the Shepparton gauge level exceeds 10.36 m (110.487 mAHD) with all bars being removed 24 hours after the river level at Shepparton exceeds 10.96 m.

2.2 The Broken System

2.2.1 Overview

Diverters in the upper Broken Creek are supplied by diverting water from the Broken River at Casey's Weir. Following the implementation of the "Return of Lake Mokoan to Wetlands" project, Lake Nillahcootie will be the only significant storage in the Broken System.

2.2.1.1 System Entitlements

There is 32,190 ML of entitlement in the Broken System, of which 5,960 ML is stock and domestic. Of the stock and domestic entitlement 5,380 ML is currently associated with the Tungamah Stock and Domestic Scheme which is to be pipelined and supplied from the Goulburn System. Of the total entitlement 5,960 ML is held in the upper Broken Creek.

2.2.2 Lake Nillahcootie

Lake Nillahcootie is situated south of Benalla and at full supply level of 264.5 mAHD has a capacity of 40,000 ML and fills in most years. Regulated releases of up to 1,800 ML/d can be made via two valves connected to the outlet tower by a 1800 mm diameter steel pipe.

2.2.3 Upper Broken Creek

Upstream of Katamatite, diversions from the Broken River at Casey's Weir, which can deliver flows up to 220 ML/d, provide regulated flows in the Broken Creek. Diversions are made to meet demands of regulated diverters upstream of Waggarandall Weir and the requirements of the Tungamah Stock and Domestic System. The Tungamah system demand from the Creek will cease once the Tungamah Stock and Domestic pipeline has been completed. If unregulated inflows are insufficient to meet the diversion requirement then water is regulated from the Broken storages to satisfy this demand. Once Lake Mokoan has been returned to a wetland flows will be regulated from Lake Nillahcootie

In the last irrigation season an additional diversion to the Broken Creek was undertaken with the intention of passing it to the lower Broken Creek to assist in meeting environmental objectives. The flows diverted from the Broken River were surplus to in-valley requirements.

2.2.4 Lower Broken Creek

Irrigation demands in the lower Broken Creek are supplied by regulated inflows from the Murray Valley and Shepparton Irrigation districts. Unregulated inflows to the lower Broken Creek are received from channel outfalls, drains and the upper Broken Creek. The Goulburn Bulk Entitlement (BE) provides up to 40,000 ML to be regulated to the Broken Creek from the East Goulburn Main Channel. Any shortfall in the volume of water from the Goulburn can be provided from the Murray System when Goulburn allocations are lower the Murray allocations.

Additional regulated flows into the Broken Creek can be made by declaring that a regulated flow passing Rice's Weir for environmental outcomes is a River Murray Inflow. Additional flows from the Goulburn can be debited against the inter-valley trade accounts, the water quality entitlement held in Eildon or diverted during surplus flow periods in the Goulburn. Additional flows from the Murray are accounted as a return flow from the volume diverted from Lake Mulwala into the Yarrawonga Main Channel. In 2005 regulated flows were passed from the upper to the lower Broken Creek for environmental purposes. Regulated flow rates from the upper Broken Creek are limited to a maximum of 30-40 ML/d due to limited creek channel capacity between Waggarandall Weir and Katamatite.

There are 16 channel outfalls into the Lower Broken Creek. Of these 11 are from Murray Valley channels while 5 are from Shepparton channels. Regulated inflows to the Broken Creek from the Murray Valley system are delivered from the No 6 Channel either from the end, or Flanner's outfall or Jewel's outfall having a total capacity of 55 ML/d or up to 80 ML/d from the Katamatite outfall of the No 3 Channel. Regulated supply from the Shepparton Irrigation Area is generally delivered from the East Goulburn Main Channel with an outfall capacity of around 250 ML/d. The Shepparton No 12 Channel, with a total outfall capacity of around 20 ML/d has also been used to supply regulated outfalls. Total capacity of the outfalls exceeds 600 ML/d, however capacity sharing with irrigation demand restricts the actual volume that can be passed to the Broken Creek. The maximum outfall capacity from during peak irrigation demand is around 300 ML/d.

A total of 11 drains enter the Broken Creek with 5 from the Murray Valley Irrigation Area and the other 6 from the Shepparton Irrigation Area.

In the Lower Broken Creek there are 11 weirs with the lower 8 weirs from Nathalia downstream having SCADA and fishways. The fishways can operate when there is a 35 ML/d flow passing through the Broken Creek. The weirs are operated to meet irrigation requirements and to pass environmental flows down and past Rice's Weir.

2.3 The Campaspe System

2.3.1 Overview

The Campaspe catchment covers an area of 5,172 km^2 and includes two regulated supply systems. The Coliban System is operated by Coliban Water and supplies both urban and irrigation requirements from the Coliban River. The Campaspe System is operated primarily by Goulburn-Murray Water and supplies irrigation demands downstream of Lake Eppalock and part of Bendigo's urban demand. The capacity of Lake Eppalock is shared between Goulburn-Murray Water and Coliban Water.

2.3.1.1 System Entitlements

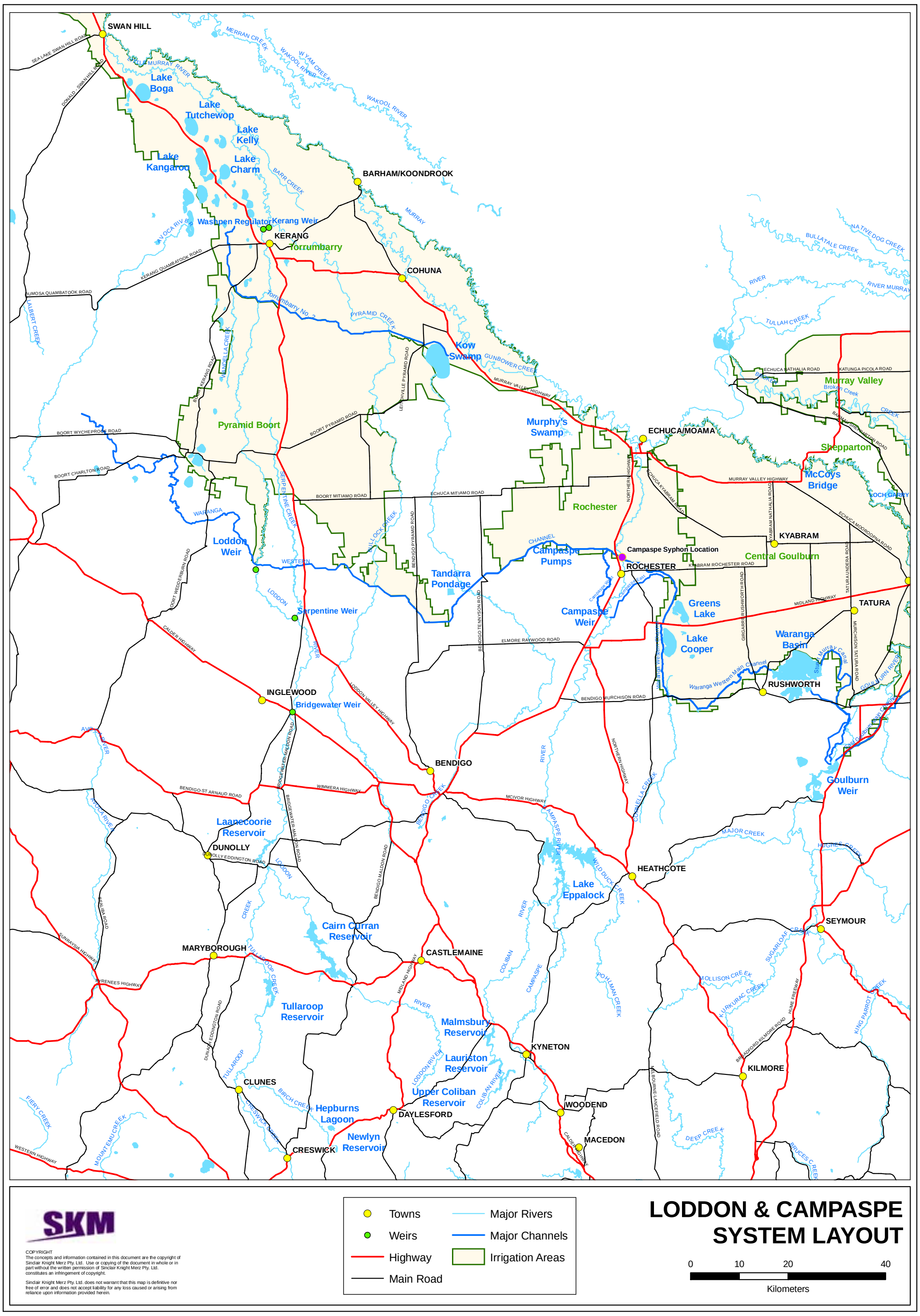
The 1999 Campaspe Bulk Entitlement Conversion Orders quantified the primary entitlements in Table 4. Water trading since 1999 has resulted in a reduction in entitlements. At the end of the 2004/2005 water year, the Campaspe Irrigation District had a total entitlement of 20,280 ML, diverters between Eppalock and Campaspe siphon had 16,330 ML and Coliban Water had 51,981 ML of entitlement.

- **Table 4 Entitlement Volumes – Bulk Entitlement Conversion Orders**

Supply System	Total Entitlement (ML)
Goulburn-Murray Water	
Campaspe Irrigation District	20,719
Eppalock to Campaspe Siphon	16,551
Campaspe Siphon to River Murray	1,857[1]
Coliban Water	
From Eppalock and Coliban Storages	50,260[2]
Goornong, Axedale	1578
Rochester	143

(1) Defined as Partially Regulated in the Bulk Entitlement
(2) Annual average over a 3 year period includes urban and rural customers, 17,440 of total can be taken from Eppalock

In addition to the primary entitlements, the Campaspe System can also provide water to supplement flows in the Waranga Western Channel (WWC) to assist in overcoming capacity constraints during peak demand periods. Regulated diversions from the Campaspe System to the Goulburn System can commence once Campaspe allocations exceed 110% of water right, with a maximum diversion of 24,700 ML once allocations exceed 150% of water right. An additional 4,000 ML can be diverted to the Goulburn System from unregulated flows in the Campaspe River. This is explained further in Appendix E.



■ **Figure 4 Campaspe and Loddon Systems**

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2.3.2 Coliban System

Water storage in the Coliban System is comprised of the Upper Coliban, Lauriston and Malmsbury storages. The majority of the water diverted from the Coliban System occurs at Malmsbury Reservoir, the furthest downstream of the storages. The storage holds 17,780 ML at Full Supply Level (FSL) and supplies the Coliban Main Channel at rates from 45 ML/d to 260 ML/d. A 200mm diameter conduit from the main pipe allows up to 10-15 ML/d to be released at the main channel to meet minimum flow requirements downstream of the reservoir. These flows are allowed to enter the river from an outfall from the channel of approximately 30 ML/d capacity immediately downstream of the outlet works. Direct releases to the river are made using up to 9 spillway gates if the water level is within 2.1 m of FSL.

The storage and discharge capacities of the storages are shown in Table 5.

- **Table 5 Upper Coliban Capacity**

Storage	Capacity (ML)	Outlet Valve Capacity to River (ML/d)	
		Min	Max
Upper Coliban	37,480	20	380
Lauriston[1]	19,800	50	900
Malmsbury	17,780	0	~30

(i) Lauriston has a gated spillway and regulated releases can be made via the gates at higher water levels

2.3.3 Lake Eppalock

Lake Eppalock was constructed in the 1960's and holds 312,000 ML at its Full Supply Level of 193.91 m AHD. The dam is formed by an earth and rock fill embankment and a fixed crest, free overfall, concrete spillway with a discharge capacity of 141,900 ML/d. Discharges to the Campaspe River are made through an 1150 mm cone dispersion valve or through the Coliban Water pump station. At Full Supply Level, 1,850 ML/d can be discharged through the valve.

The pump station is comprised of three turbines that can utilise releases to drive pumps that can supply up to 90 ML/d to Bendigo via a pipeline. A minimum flow of 120 ML/d is required to operate one turbine and the maximum flow through all turbines is 750 ML/d.

The capacity of Lake Eppalock is shared between Goulburn-Murray Water with access to 82% of capacity and Coliban Water with 18% of capacity. Inflows into the storage are shared in the same ratio as the storage capacity. The available resource for each authority is continuously accounted by Goulburn-Murray Water as the appointed storage operator.

Regulated releases are made to meet demands to the Campaspe Irrigation District from Campaspe Weir, supplements to the Goulburn system, irrigation demand of river diverters and minimum flow requirements. Travel times mean that releases from Lake Eppalock to meet demands from Campaspe Weir must occur two days ahead of their planned diversion from the weir pool.

2.3.4 Campaspe Weir

Campaspe Weir pool has a capacity of approximately 2,626 ML at a Full Supply Level of 120.42 m AHD. Water is diverted by gravity from the weir pool into the Campaspe Irrigation District.

The G-MW Campaspe Bulk Entitlement allows up to 270 ML/d to be diverted to the Campaspe West area through the Campaspe No. 1 Channel offtake and 105 ML/d to the Campaspe East area through the Campaspe No. 2 Channel offtake. Around 50 ML/d can be passed through the East and West channels to supplement Waranga Western Channel flows as previously discussed.

The weir pool can be operated below FSL to provide opportunities for re-regulation and harvesting although during periods of high irrigation demand the drawdown may be restricted to 100mm. With restricted allocations in recent years, peak demands have been lower and the weir pool has been operated up to 300mm below FSL without restricting planned diversions. The discharge capacity of the Campaspe No 2 offtake is more sensitive to pool level fluctuations at Campaspe Weir than the Campaspe No. 1 offtake.

Water is released through the weir to meet private diverter requirements between the weir and the Campaspe Siphon and to provide minimum passing flows specified in the BE below the Siphon. The regulating gate at the weir has a capacity of 107 ML/d at FSL and higher flows will spill over the weir crest.

2.3.5 Lower Campaspe River

Below Campaspe Weir the significant regulation point is where the WWC passes underneath the Campaspe River at the Campaspe Siphon near Rochester. At the siphon it is possible to either pump water from the Campaspe River into the WWC or to provide additional flow in the river by outfalling water from the WWC to the river.

The WWC outfall structure has 5 regulating gates that were traditionally used to outfall surplus water due to rainfall rejection and to occasionally pass high flows from Wanalta Cornella Creek that can enter the WWC at a regulator upstream of the Campaspe River. It is estimated that under free flow conditions up to 2,300 ML/d could be outfalled (Bill Viney, G-MW pers.comm.) although previous operation manuals defined a maximum release of 1,470 ML/d. In recent years small outfalls have occurred to provide environmental flows in the Campaspe River downstream of the siphon and to pass flow to the River Murray.

Diversions from the Campaspe River to supplement flows in the WWC are accomplished by a pump station with a capacity of up to 500 ML/d. These flows will be called on if there is supplement

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available from the Campaspe System and WWC downstream demands exceed delivery capacity in the WWC upstream of, and through, the siphon.

Prior to the introduction of minimum flows passing the Campaspe Siphon, a targeted passing flow of 15 ML/d was provided for private diverters. The entitlements for private diverters downstream of the siphon are defined in the BE as partially regulated.

2.4 Loddon River System

2.4.1 Overview

The Loddon catchment covers 15,320 km^2 with the three main streams being the Loddon River, Tullaroop Creek and Bet Bet Creek. The major storages are Cairn Curran, Tullaroop and Laanecoorie Reservoirs and they are used to supply regulated water to private diverters upstream of Loddon Weir and water to the Boort Irrigation District. Birches (Bullarook) Creek is a separate supply system upstream of Tullaroop Reservoir and includes two storages (Newlyns and Hepburn).

2.4.1.1 System Entitlements

Entitlements in the Bullarook/Birches Creek system total 909 ML of which 100 ML is reserved for the townships of Springhill and Clunes.

Table 6 gives the volumes of entitlement defined in the Loddon System Bulk Entitlement Conversion orders. These entitlements may be restricted by allocations depending on resource availability in any given season. The Bulk Entitlement Conversion orders also provide for environmental and urban carryover accounts.

Table 6 Water Entitlements in the Loddon System

	Regulated Annual Entitlements		Other Entitlements (ML)
Supply	Licence (ML)	D&S (ML)	
Cairn Curran Dam to Laanecoorie Reservoir	1468	154	
Tullaroop Dam to Laanecoorie Reservoir	3028.5	28	
Laanecoorie Reservoir to Bridgewater	6642.4	170	
Bridgewater to Loddon Weir (including Serpentine Ck)	10044.5	160	
East Loddon Water Works District		1,600[1]	
Coliban Water			820
Central Highlands			1,200
Wetland Entitlement			2,000

1. Annual average over a 3 year period

The Boort Irrigation Area is supplied from both the Goulburn and Loddon systems, depending on water availability in each system. Water can be made available from the Loddon system if there is sufficient water in store to supply high reliability entitlements in the Loddon system in the current and following irrigation seasons.

Seasonal allocations in the Loddon system are normally linked to those in the Goulburn system. When allocations are 100% or less, they are usually the same in the two systems. Sales allocations in the Loddon system commence when Goulburn allocations are 110%, and remain 10% less than the Goulburn allocation. However, if the Loddon system has insufficient resource to provide allocations relative to the Goulburn system, the Loddon system can have lower allocations. Stock and Domestic and urban allocations can vary from the general Loddon allocation. Their minimum allocation is 50% of entitlement and is restricted to a maximum allocation of 100% of entitlement.

2.4.2 Birches Creek Storages

The Birches Creek System is located upstream of Tullaroop. It includes two storages - Newlyn Reservoir (2,970 ML capacity) and Hepburn Lagoon (2,500 ML capacity).

The discharge capacity of the outlet works at Newlyn Reservoir when full is 35 ML/d. In recent years the storage has been drawn down to around 16% (500 ML) of capacity. At these low levels G-MW has been able to discharge around 5 ML/d to meet downstream irrigation demands.

Discharges of up to 25 ML/d are possible from Hepburn Lagoon when it is full. As with Newlyn Reservoir, the storage has been drawn down to low levels in recent years. A practical minimum operating level of around 10% capacity has been set for the storage and at these levels flows of only 1 ML/d can be provided.

2.4.2.1 Cairn Curran

Cairn Curran Reservoir was completed in 1956 and has a capacity of 148,760 ML at a Full Supply Level of 208.46mAHD. The dam has an earth and rock fill embankment and a gated spillway with three radial gates.

- **Table 7 Cairn Curran Outlet Works: Discharge Capacities and Operating Ranges**

Outlet	Discharge Capacity at FSL (ML/d)
Irrigation Outlet	750
Turbines (total)	810
Spillway	189,000

Releases of less than 220 ML/d are passed through the irrigation outlet valve. Once releases reach 220 ML/d, flows can be passed through the hydropower station up to its capacity of 810 ML/d at FSL. If the required discharge exceeds the hydropower station capacity then the irrigation outlet is used to supplement the hydropower station release.

Releases greater then the outlet and hydropower station capacity can be made by operating the spillway gates. The minimum opening for the spillway gates is 100 mm for short term releases and for continuous releases a gate opening of 200 mm is recommended. At FSL a gate opening of 200 mm corresponds to a flow of 720 ML/d through one gate.

2.4.2.2 Tullaroop Reservoir

Tullaroop Reservoir was completed in 1959 and has a capacity of 73,690 ML at 222.80 m AHD. The dam consists of an earth and rock fill main embankment and a concrete free overfall main spillway with a discharge capacity of 70,950 ML/d. The discharge capacities through the 1,050 mm irrigation outlet and the urban outlet at FSL are shown in Table 8. The urban outlet is only available if it is not supplying the Maryborough pump.

- **Table 8 Tullaroop Outlet Works: Discharge Capacities and Operating Ranges**

Outlet	Discharge Capacity at FSL (ML/d)	Approximate Minimum Operating Level m AHD(%Capacity)
Irrigation Outlet	730	206.20 (5%)
Urban outlet	42	205.7 (4%)

2.4.2.3 Laanecoorie Reservoir

The storage at Laanecoorie was completed in 1891 and enlarged in 1935. Full Supply Level is 160.20 m AHD with 7,930 ML/d of water being held in store. The concrete spillway is topped by 26 tilting gates that operate once FSL is exceeded. Four irrigation valves in the spillway structure can supply around 1,300 ML/d of regulated discharge downstream of the storage.

Laanecoorie provides the ability to re-regulate releases from Cairn Curran and Tullaroop and also provides opportunities to harvest additional water. During recent irrigation seasons Laanecoorie has a minimum target operating volume of 4,000 ML whereas previously with more water in the system it was operated at 5,000 ML. If inflows result in Laanecoorie exceeding the target level then the additional water in Laanecoorie is used to meet downstream flow requirements. Toward the end of the irrigation season Laanecoorie is usually drawn down to sill level (158.65 m AHD, 2,940 ML). In recent years with low volumes in the upper storages Laanecoorie has been drawn down lower than the sill level. The timing of the drawdown is dependent on providing supply to meet the irrigation demands of pump diverters on the Laanecoorie weir pool.

2.4.2.4 Laanecoorie to Loddon Weir

There are two weirs on the Loddon River between Laanecoorie and Loddon Weir. Bridgewater Weir forms a pool from which water is diverted to the East Loddon Water Works district and to a race supplying the Water Wheel Flour Mill. The water diverted to the mill returns to the Loddon River downstream of Bridgewater Weir. The weir has a fixed crest with no flow regulating structures.

Serpentine Weir is a fixed crest weir that allows water to be diverted to Serpentine Creek during normal regulated flows. Goulburn-Murray Water is planning to install a regulating gate at the weir with a capacity of around 36 ML/d when the weir is at FSL. Prior to the construction of the weir, Serpentine Creek would receive water from the Loddon River at moderate or higher flows.

Flows from the Waranga Western Channel pass through the Loddon Weir pool. The Waranga Western Channel has a capacity of 550 ML/d to the east of the Loddon River (before it passes through the weir pool) and a capacity of 1,100 ML/d to the west of the river. The increased capacity of the Waranga Western Channel to the west of the River reflects the ability of the Loddon Supplement to provide additional flows into the Boort Irrigation District. During 2006 an overshot gate is to be installed at Loddon Weir to allow better regulation of flows up to 70 ML/d. Total gate capacity will then be in the order of 1,000 ML/d. The improved regulation of smaller flows through the new gate will allow better conformance with environmental flow requirements downstream of Loddon Weir. Water can be released downstream of the Loddon Weir from either the Loddon supply system or the Goulburn supply system via the Waranga Western Channel.

2.4.2.5 Lower Loddon River

Kerang Weir has a fixed crest and a minimum discharge level of 75.15 m AHD. It creates a pool that allows up to 850 ML/d to be regulated to the Kerang Lakes system through the Washpen regulator. Inflows to Kerang Weir are via the Torrumbarry System from Pyramid Creek or the Torrumbarry No. 2 channel and the upper Loddon River. Regulated flows to supply demands from or below Kerang Weir are sourced from the Torrumbarry System. Around 100 ML/d is passed downstream of Kerang Weir to supply private diverters (SRWSC 1983).

Flood operations downstream of Loddon Weir are aimed at passing flood flows north to the River Murray and mitigating flood peaks by regulating water into the Kerang Lake System (SRWSC 1983). Flood waters spill from the main Loddon River into anabranches and distributaries downstream of Loddon Weir. The proportion of spill varies with flow but commences when flows downstream of Loddon Weir exceed 1,600 ML/d (SRWSC 1983).

A proportion of the flood flows to Kerang Weir can be diverted to the Kerang Lakes via the Washpen regulator. However the volume of diverted flows depends on the volumes in the Lakes and any other inflows to the Lakes including the Wandella Creek, Sheepwash Creek, the Avoca River and the available capacity of the No 7 outfall from the 6/7 channel. Flows to Sheepwash Creek commence once the level at Kerang Weir exceeds 75.59 m AHD (SRWSC 1983).

2.5 Impacts of Operation on Flow Regimes

The construction and operation of reservoirs to provide irrigation and urban water supply storage has altered the natural flow regimes of the rivers in the study area. These impacts are briefly described below.

The figures in Appendix L show winter and summer Flow Duration Curves (FDCs) of natural and current flow data for the five environmental flow reaches of the Goulburn River (described below) as well as five river reaches in the Campaspe and Loddon catchments: the Coliban River, Campaspe River, Loddon River, Tullaroop Creek and Birches Creek.

The Scientific Panel which recommended environmental flow regimes for the Goulburn River (refer Chapter 3) divided the River below Eildon into five environmental flow reaches, namely:

- Reach 1 – Eildon to Molesworth;
- Reach 2 – Molesworth to Seymour;
- Reach 3 – Seymour to Nagambie (Goulburn Weir);
- Reach 4 – Nagambie to Loch Garry; and
- Reach 5 – Loch Garry to the River Murray.

The winter FDCs are for modelled daily flows from 15 May until 15 August (non-irrigation season). The summer FDCs are from 1 December until 30 April. The time series of modelled and natural flows cover a 25 year period in the of the Goulburn River reaches, a 114 year period for the Campaspe River, a 30 year period for the Loddon River and Tullaroop Creek, and a 43 year period for Birches Creek.

2.5.1 The Goulburn Environmental Flow Reaches

Natural flow is greater than current flow over the **non-irrigation season** for all environmental flow reaches on the Goulburn due to water being harvested during these months. Summer releases from Lake Eildon for the purposes of irrigation supply mean that flows are kept unnaturally high in reaches 1-3.

Typical releases from Eildon during the irrigation season are of the order of 10,000 ML/d. This is evident in the summer FDCs for reaches 1-3. Flows of this magnitude are shown to occur approximately 38% of the time.

For all reaches, the difference between natural and current flows is less pronounced at high magnitude events over summer, whereas in winter a difference can be seen. This is due to water harvesting during winter for irrigation supply.

This impact can also be seen when examining the flood frequency curves in Appendix M and.

The graphs in Appendix M show the reduction in flood flows caused by the introduction of the Eildon Dam, and reflect the current dam operation. It can be seen that the reduction in flood magnitudes becomes less pronounced further downstream from the Reservoir. This is to be expected as the flows from Eildon under natural conditions attenuate as they move downstream, and the peak flow becomes more heavily dependent on tributary inflows.

Reach 4 is located below Goulburn Weir and the influence of the weir is evident in the FDCs for both winter and summer. The weir regulates the flow and releases an average weekly minimum of 250 ML/d, (which occurs approximately 72% of the time in the non-irrigation season and 79% of the time in summer). The natural flow is below current flow at low magnitudes, which shows natural flows would sometime be less than the regulated flow.

Reach 5 is less regulated than the other reaches, so that the natural flow is larger than the current flow during both summer and winter.

2.5.2 Broken Creek

In the upper Broken Creek's regulated reaches upstream of Waggarandall Weir irrigation requirements have caused a reversal in seasonal flow patterns, an elimination of cease to flow periods and an overall increase in flows all year round (CRCFE 2001). Below Waggarandall Weir at Katamatite flows more closely resemble the natural flow regime with peak flows in August and September and low flows occurring in March (SKM 1998).

Under natural flow conditions the Lower Broken Creek would be a winter/early spring flowing ephemeral stream (GHD 2005). It is now a series of permanent weir pools with maximum mean daily flows occurring during peak irrigation demand periods during summer months. In 1998 the

Broken Creek Management Strategy (SKM, 1998) estimated that the Lower Broken Creek had a bank full capacity of approximately 3,000 ML/d. Any flows above this would create flooding along the Creek.

2.5.3 Campaspe System

The flow duration curves for Reach 1 (Coliban River from Malmsbury Reservoir to Lake Eppalock) show that the summer releases from Malmsbury Reservoir are lower than the natural flows and flows are lower in summer than in winter. There is no flow in summer for approximately 30% of the time. The Bulk Entitlement, which has been in place since 2002, requires an 8 ML/d, or natural, passing flow below Malmsbury Reservoir. The FDCs show that flows are less than 8 ML/d more than 45% of the time in summer, and more than 25% of the time in winter. Unlike other reaches of Campaspe system, there is no reversal of seasonality in Reach 1.

Reach 2 (Campaspe River from Lake Eppalock to Campaspe Weir) flows are significantly higher than natural flows in summer, when the River is used as an irrigation carrier.

Flows to reach 3 (Campaspe Weir to Campaspe Siphon) are regulated from Campaspe Weir. Current flow is sometimes higher than natural, particularly in autumn when flows are frequently released to supplement supplies to the Waranga Western Channel.

Similarly to reach 1, flows in reach 4 (Campaspe Siphon to River Murray) are lower in summer than in winter. The current summer low flows are however still larger than natural low flows in this reach.

For Campaspe system reaches, the difference between natural and current high flows is less pronounced in summer than in winter. This is due to water harvesting during winter for irrigation supply.

2.5.4 Birches and Tullaroop Creeks

For all reaches of Birches Creek the current flow is less than the natural and recommended flow components, except for the summer low flow regime. Winter flows are more similar to the natural flows than summer flows.

Current flows are less than natural flow in the non-irrigation season in Tullaroop Creek downstream of Tullaroop Reservoir, due to water being harvested during these months. Summer flows are higher than natural in the same reach due to irrigation releases.

2.5.5 Loddon River

Current flows are less than natural flow in the non-irrigation season for all reaches of the Loddon River due to water being harvested during these months. Summer flows are higher than natural in the Loddon between Cairn Curran and Loddon Weir (Reaches 1 to 3b) due to irrigation releases. For Reach 4 (Loddon Weir to Kerang Weir), a 17 ML/d flow is passed most of the time for stock and domestic (S&D) and minimum passing flows, and current flows are less than natural throughout the year.

Summer flows in Reach 5 (Loddon Weir to River Murray) are significantly higher than in Reach 4 due to irrigation releases, particularly from Pyramid Creek. In the non-irrigation season, flows are generally low in Pyramid Creek due to harvesting in Kow Swamp, and Reach 5 is dry for over 20% of the time.

For all reaches of the Loddon, the difference between natural and current high flows is less pronounced in summer than in winter. This is due to water harvesting during winter for irrigation supply.

3. Environmental Flow Recommendations

3.1 Overview

This chapter provides information on the environmental flow recommendations for the Goulburn River, Broken Creek, Coliban River, Campaspe River, Birches Creek, Tullaroop Creek and Loddon River. The chapter is divided into five sections. Section 3.2 provides information on the development of environmental flow recommendations. Sections 3.3 to 3.7 provide information on the environmental flow recommendations as well as conformance statistics for the systems mentioned above. A brief summary of this chapter is provided in Section 3.8.

3.2 Introduction

Environmental flow recommendations for the Goulburn River below Lake Eildon have been developed by a Scientific Panel ("the Goulburn Scientific Panel") led by Peter Cottingham of the CRC for Freshwater Ecology. When setting environmental flow recommendations, the Goulburn Scientific Panel assessed the flow-related issues that potentially pose a risk to the environmental and ecological values of the Goulburn River (Cottingham et al, 2003). That is, the Goulburn Scientific Panel examined flow requirements from an ecological perspective only. Therefore, some flow recommendations conflict directly with the Goulburn's current status as a 'working river' that is used for the purpose of supplying water for irrigation.

No formal environmental flow recommendations have been developed for Broken Creek. In place of formal environmental flow recommendations, the Steering Committee has developed preliminary flow requirements for the maintenance of fish ladders and the management of Azolla. (Azolla is a floating fern that under low flows, warm temperature and high nutrient loads can blanket the surface of waterbodies, particularly weir pools and dams. When Azolla dies, the decomposition process can affect oxygen levels in the water column, and this may contribute to increased risk of fish kills.)

SKM has developed environmental flow recommendations for the Campaspe River (SKM, 2006), and for Birches Creek and Tullaroop Creek, from Creswick Creek to Tullaroop Reservoir (SKM, 2005a; 2005b). Environmental flow recommendations for the Loddon River have been developed by a Scientific Panel ("the Loddon Scientific Panel"). The Loddon Scientific Panel has also developed environmental flow recommendations for Tullaroop Creek below Tullaroop Reservoir (Loddon River Environmental Flows Scientific Panel, 2002).

The Goulburn River Scientific Panel, the Loddon River Scientific Panel and SKM all used the FLOWS method to develop environmental flow recommendations for the studied reaches. The FLOWS method has been specifically developed for determining environmental water requirements in Victoria (DNRE, 2002). The method is based on the concept that key components of the natural flow regime influence various biological, geomorphological and physicochemical processes in rivers and streams.

Preliminary flow recommendations have also been developed that would enable Victoria to fulfil its commitment to the Living Murray Initiative. This initiative is a river restoration project funded by both State and Federal governments, which aims to restore the health of the River Murray. The flows for the Living Murray contribution are estimates only and have been prepared by the Steering Committee for the purposes of the current project. All Living Murray flow requirements are in addition to current flows and/or other environmental flow requirements.

3.3 Goulburn River

The Goulburn Scientific Panel divided the Goulburn River below Eildon into five environmental flow reaches, namely:

- Reach 1 – Goulburn River: Eildon to Molesworth;
- Reach 2 – Goulburn River: Molesworth to Seymour;
- Reach 3 – Goulburn River: Seymour to Nagambie (Goulburn Weir);
- Reach 4 – Goulburn River: Nagambie to Loch Garry; and
- Reach 5 – Goulburn River: Loch Garry to the River Murray.

The compliance point for Living Murray contributions has not been specified. But as these recommendations assume that flow will be delivered to the Murray River it is assumed that the compliance point is (or is downstream of) Reach 5.

3.3.1 Environmental flow recommendations

Summer Low Flow

Summer low flow recommendations have been specified for all five environmental flow reaches. Reaches 1 to 3 have similar low flow requirements, and these vary significantly from the low flow requirements of Reaches 4 and 5. In Reaches 1 to 3, summer releases from Lake Eildon for the purpose of irrigation supply mean that flows are kept unnaturally high ("seasonal flow inversion"). The Goulburn Scientific Panel has set a range of summer low flow recommendations for Reaches 1 to 3 that specify a maximum recommended flow (refer Table 9).

Two or more summer low flow recommendations are made for Reaches 1 to 3, each addressing a specific ecological requirement. At first appearance these flow recommendation appear to be in conflict. For example, in the case of Reach 1, the summer low flow recommendation to provide for riffle habitat is for flows to be maintained below 2,000 ML/d. But to prevent high water velocity, flows must be maintained below 2,700 ML/d on average. Peter Cottingham has been queried on this, and his response was that the flow recommendations represent "a sliding scale of potential habitat reinstatement" (*pers. comm.*, P. Cottingham, 12-May-2006). At 2,700 ML/d, you would start to "get the desired reduction in flow velocity that would allow aquatic macrophytes to persist", but at 2,400

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ML/d "you would have the slow water and the shallow water areas that would favour aquatic macrophyte persistence and spread". Flows of 2,000 ML/d would be even better, providing slow water, shallow water and extra riffle habitat.

Summer flows in Reaches 4 to 5 are lower than natural. Hence the Scientific Panel has set a minimum flow recommendation for these river reaches. Inter-Valley Trade (IVT) is the trade of water between different water supply systems. IVT is already occurring in the Goulburn Basin and may increase the volume of flows below Goulburn Weir, without increasing flows above the Weir. At a later stage it may be necessary to investigate a summer range of flows to operate within, rather than just a summer minimum to prevent IVT from resulting in excessive summer flow in the lower Goulburn.

Summer freshes

No specific flow recommendations relating to summer freshes were developed for Reaches 1 to 3. The Goulburn Scientific Panel has acknowledged that seasonal flow inversion meant that in-channel benches are inundated more frequently than natural (e.g. 3-4 events, versus 1-2 events naturally), but for expended periods of time (e.g. 60-80 days, versus 1-8 days naturally). In order to achieve a more natural pattern of bench inundation, water levels in Reaches 1 to 3 would have to be maintained below 3,000 ML/d.

The Goulburn Scientific Panel felt that the current frequency and duration of summer freshes in Reaches 4 and 5 approximate the natural pattern. The Goulburn Scientific Panel was concerned that water savings and better management of rain rejections (e.g. through Total Channel Control) would reduce the current freshes that occur in Reaches 4 and 5. These would need to be protected in the future if improved irrigation efficiencies resulted in a reduction in freshes associated with rain rejections.

Spring over-bank

The Goulburn Scientific Panel recommended that an annual floodplain inundation event should be reinstated to the Goulburn River downstream of Lake Eildon to Murray confluence. Such events are necessary for wetland inundation, to maintain the natural level of floodplain biodiversity and function (Cottingham *et al.*, 2003). The Goulburn Scientific Panel believed that it would be necessary to vary the magnitude of the flood peak. A single event magnitude (e.g. 20,000 ML/d) may result in the wetting of some wetlands on the floodplain, but not others located at higher levels. To this end, the Goulburn Scientific Panel recommended that the flow magnitude should be varied between 15,000 ML/d and 60,000 ML/d and that the distribution of flood peaks should be based on a doubling of the natural recurrence interval for flow magnitudes. An annual over-bank flood event would not be required in years when such an event would not have been experienced naturally (i.e. a drought year).

Rates of rise and fall

Rapid changes in water level can cause bank instability and can wash away juvenile fish and invertebrates (Cottingham *et al.*, 2003). The Goulburn Scientific Panel has set maximum rates of rise and fall for the reaches directly downstream of regulatory structures, namely Reaches 1 and 4.

Living Murray contribution

Living Murray contributions have been defined to provide specific environmental benefits to downstream reaches. For example, spring low flows have been set to water Gunbower Forest and Perricoota Forest. Summer freshes have been set to top up wetlands in January or February. Summer low flows have been set for downstream sites like the Murray Mouth and spring freshes have been set to enable over-bank flooding in the Murray River. All Living Murray flow requirement are in addition to current flows and/or other environmental flow requirements.

3.3.2 Conformance calculation method

There is no current requirement to comply with the environmental flow recommendations developed by the Goulburn Scientific Panel. However, compliance was calculated for defined flow requirements in order to identify constraints for the delivery of environmental flow recommendations. For example, in the case of summer low flows in Reach 4, the environmental flow recommendation is complied with on 5% of days in the summer period. We can ask ourselves why this is so? Is it because of the way in which the Goulburn Weir is operated? Or is it because there is no available water?

Low flow and fresh environmental flow compliance in the Goulburn River was assessed using 25 years of modelled flow data representing both the natural and current level of development. The natural flow data was the same as that used by the Goulburn Scientific Panel, but the Panel used gauged flow in place of current data.

In the case of the Living Murray requirements, large flows are required for extended periods of time to benefit downstream sites. These flows would be required on demand. That is, they could be called for at any time and in a period that does not necessarily correspond to a time of high flow in the Goulburn River. We cannot test to see if Living Murray requirements have been available historically on demand – because there has been no demand. What we can test is whether flows of the specified magnitude and frequency have been recorded in the past and then consider if not, why not? For example, are there channel capacity constraints that restrict the volume of water that can be delivered to the lower reaches of the Goulburn River?

It is important to note that during the last five years there has been considerable trade of water out of the study area (IVT). This change could influence compliance calculations by increasing summer flows in Reaches 4 and 5. Also, Lake Mokoan will eventually be decommissioned and this will affect compliance calculations; most likely somewhat decreasing compliance with low

Table 9 Environmental flow recommendations for the Goulburn River below Eildon (after Cottingham et al., 2003)

Reference(s)	ref1 - Cottingham P., M. Stewardson, D. Crook, T. Hillman, J. Roberts and I. Rutherfurd, 2003, Environmental flow recommendations for the Goulburn River below Lake Eildon. Cooperative Research Centre for Freshwater Ecology, Technical Report 01/2003, November 2003. ref2 - Earl G., 2006, Goulburn-Campaspe-Loddon Infrastructure Study. Murray and Broken Creek Environmental Flow Scenarios. Tributary Contributions to Murray. Notes distributed during project inception meeting held 1-May-2006.											
	REACH NUMBER AND NAME											
Season and Component	Reach 1		Reach 2		Reach 3		Reach 4		Reach 5		Living Murray contribution	
	Lake Eildon to Molesworth		*Molesworth to Seymour*		*Seymour to Nagambie*		*Nagambie to Loch Garry*		*Loch Garry to the River Murray*		*Conformance assessed at Reach 5*	
	Recommendation	Conformance	Recommendation	Conformance	Recommendation	Conformance	Recommendation	Conformance	Recommendation	Conformance	Recommendation	Conformance
SUMMER LOW FLOW	Summer/Autumn mean *(Relating to high water velocity)* <0.6 m/s, ie approx <2,700 ML/d or natural (ref1 p. 27)	Summer low is <2,700 ML/d in 26% of days in period (average flow not calculated)					Allowable minimum flow *(For availability of deep water habitat)* >610 ML/d or natural (ref1 p. 49)	5% of days in period	Allowable minimum flow *(For availability of deep water habitat)* >610 ML/d or natural (ref1 p. 49)	36% of days in period	JAN to MAR - Current bulk entitlement of >350 ML/d, plus >1,000 ML/d. Total = 1,350 ML/d - annually for d/s sites - for 3 months (ref2 p. 1)	7% of days in period
	Summer/Autumn max *(For availability of riffle habitat)* <2,000 ML/d or natural (ref1 p. 29)	24% of days in period	Summer/Autumn max *(For availability of riffle habitat)* <3,000 ML/d or natural (ref1 p. 29)	26% of days in period	Summer/Autumn max *(For availability of riffle habitat)* <3,000 ML/d or natural (ref1 p. 29)	26% of days in period						
	Summer/Autumn max *(For shallow water habitat)* <2,400 ML/d (Jan) <1,400 ML/d (Feb, Mar) (ref1 p. 31)	31% of days in period 6% of days in period	Summer/Autumn max *(For shallow water habitat)* <2,900 ML/d (Jan) <1,700 ML/d (Feb, Mar) (ref1 p. 31)	26% of days in period 6% of days in period	Summer/Autumn max *(For shallow water habitat)* <3,000 ML/d (Jan) <1,800 ML/d (Feb, Mar) (ref1 p. 31)	24% of days in period 6% of days in period						
SUMMER FRESHES	No specific recs (ref1 p. 37)	N/A	No specific recs (ref1 p. 37)	N/A	No specific recs (ref1 p. 37)	N/A	No specific recs, maintain natural frequency and duration of spring / summer freshes (ref1 p. 37)	N/A	No specific recs, maintain natural frequency and duration of spring / summer freshes (ref1 p. 37)	N/A	JAN to FEB - Current bulk entitlement of >350 ML/d, plus Living Murray low flow requirement, plus 1,000 ML/d. Total = 2,350 ML/d - as required to top up wetlands for 7 days (ref2 p. 1)	Volume 24% Number 1 event – 24% 2 events – 4% 3 events – 4% 4 events – 0% Duration 25%
Spring LOW FLOW											JUL to DEC - Current bulk entitlement of >250 ML/d, plus 10,000 ML/d. Total = 10,250 ML/d annually for d/s sites as required over 6 month period (ref 2 p. 1)	21% of days in period
Spring FRESHES											AUG to NOV - Current bulk entitlement of >250 ML/d, plus 20,000 ML/d from Goulb/ Camp'pe Total = 20,250 ML/d - as required to top up flood flows for 1-2 months (ref2 p. 2)	Volume 60% Number 1 event – 60% 2 events - 44% 3 events - 20% 4 events - 8% Duration 10 days – 27% 12 days – 12% 15 days – 6% 25 days – 6% 30 days – 0%
SPRING OVERBANK Floodplain inundation *(For wetland inundation)*	15,000 to 60,000 ML/d, depending on inflows to Lake Eildon (ref1 p. 43)	For ARIs <40 years, magnitude of current floods less than recommended	Recommendation as for Reach 1	For ARIs <40 years, magnitude of current floods less than recommended	Recommendation as for Reach 1	For ARIs <40 years, magnitude of current floods less than recommended	Recommendation as for Reach 1	Magnitude of current floods less than recommended for all ARIs	Recommendation as for Reach 1. Additional research required. (ref1 p. 46)	For ARIs >10 years, magnitude of current floods less than recommended		
RISE AND FALL Maximum allowable rate of rise and fall in water levels *(For ecological health and bank stability)*	95th percentile of the maximum natural rates of rise and fall - Rise 180% - Fall 76% (ref1 p. 50)	There have been occasions when the rates of rise and fall exceeded those that would have been experienced naturally (ref1 p. 50)	No specific recs (ref1 p. 50)		No specific recs (ref1 p. 50)		95th percentile of the maximum natural rates of rise and fall - Rise 135% - Fall 85% (ref1 p. 50)	There have been occasions when the rates of rise and fall exceeded those that would have been experienced naturally (ref1 p. 50)	No specific recs (ref1 p. 50)			

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flows in summer in Reach 5 but increasing winter and spring compliance due to increased unregulated flows from the Broken River.

Flood frequency analysis was used to assess the frequency of flooding events under current levels of development, which were then compared to the frequency of flooding events under natural levels of development. The time-series data described above was used. A peaks over threshold method was used to select peak events and flood frequency curves were fitted using Generalised Pareto Distribution method fitted by L-Moments.

3.3.3 Conformance results

Summer Low Flow

In Reaches 1 to 3, summer low flows in the order of 2,000 to 3,000 ML/d are only experienced in approximately a quarter of days in the summer period (refer Table 9). Summer low flow requirements in Reach 4 are only met in 5% of days, but compliance increases as you progress downstream into Reach 5.

Spring Overbank

Upstream of Goulburn Weir, floods with average recurrence intervals (ARIs) less than 40 years are generally smaller than recommended. In Reach 5, floods with ARIs less than 10 years are generally in accordance with the recommendations, but larger ARI floods are generally smaller than recommended (flood frequency plots are provided in Appendix M).

A flood frequency analysis of simulated natural and current conditions flows in the five reaches of the Goulburn River was undertaken. The results of this analysis are shown in Appendix M. The changes in flood magnitude and frequency have been summarised below in Table 10 below.

- **Table 10 Flood magnitude and frequency.**

Reach	Required increase in 10 year ARI flood magnitude. (ML/day)	Required increase in 30 year ARI flood magnitude.
Reach 1	17,000	7,000
Reach 2	18,000	7,000
Reach 3	15,000	7,000
Reach 4	5,000	5,000
Reach 5	0	7000

Living Murray contribution

Flow events of the magnitude required to fulfil Living Murray requirements were frequently experienced. However the duration of events, in particular the duration of winter freshes, did not match Living Murray requirements.

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3.4 Broken Creek

The Steering Committee has developed preliminary flow requirements designed for the maintenance of fish ladders and the management of Azolla (Table 11).

3.4.1 Environmental flow recommendations

- **Table 11 Environmental flow recommendations for the Broken Creek.**

Season and Component[1]	Recommendation	Compliance[2]
September to April Low Flows Min flow requirement *(To keep fish ladders open from September to April)*	30-40 ML/day	94 - 95% of days in period
August to April[3] Low Flows Min flow requirement *(To keep azolla moving from Aug to Nov, and potentially through to April for dissolved oxygen management)*	80-140 ML/day	67 - 80% of days in period
August to November Freshes *(Required at short notice in response to rapid azolla blooms)*	500 ML/day for 7 days	Volume – 88% of years Number 1 event – 88% of years 2 events – 51% of years 3 events – 34% of years 4 events – 17% of years Duration – 51% of years

Note:

1. Earl, G., 2006, Goulburn-Campaspe-Loddon Infrastructure Study. Murray and Broken Creek Environmental Flow Scenarios. Tributary Contributions to Murray. Notes distributed during project inception meeting held -May-2006.
2. Data analysed includes period prior to weir upgrade works undertaken in late 1990s. Since, the upgrade of the weirs the Broken Creek system has been operated more tightly.
3. The applicable season was originally August to November, but this period was adjusted to August to April based on Steering Committee recommendations made during a workshop on the 31st of May, 2006.

3.4.2 Conformance calculation method

The method for calculating environmental flow compliance was to use daily gauged flow in Broken Creek at Rice's Weir (site number 404210). The period of record was 1965 to 2006. The data set had large periods of missing data. Overall, 8.8% of data was missing due to assorted reasons, including the reach being "backed-up by downstream influence" and "equipment malfunction". The missing periods of data were in-filled using the time-series of daily flows used as input to the MSM-BIGMOD model. MSM-BIGMOD is a daily routing program for the River Murray System. The model has been developed by the Murray-Darling Basin Commission (MDBC) and has both flow and salinity modelling capabilities.

It should be noted that the compliance assessments for the Azolla related criteria were undertaken without regard for coincidence with Azolla blooms. But, as for the Goulburn River, we are primarily interested in the capacity of the system to deliver recommended flows.

3.4.3 Conformance Results

The Steering Committee has specified minimum flows for the purpose of keeping fish ladders open, to minimise Azolla accumulation and to manage dissolved oxygen. These minimum flows occur in the majority of days during the specified months. Fresh flows for flushing Broken Creek in response to rapid Azolla blooms occur in 88% of years, but we do not know if fresh flows occur at the same time as Azolla blooms.

3.5 Campaspe System

The Campaspe System below Malmsbury Reservoir has been divided into four environmental flow reaches by SKM (2006), namely:

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

The conformance point for Living Murray contributions has not been specified. But as these recommendations assume that flow will be delivered to the River Murray it is assumed that the conformance point is (or is downstream of) Reach 4.

3.5.1 Environmental flow recommendations

In the Campaspe River, summer low flows are higher than natural due to irrigation releases. Summer freshes occur within the range of storage releases, but the number and duration of fresh flows are not achieved due to a lack of variability in the system. Winter low flows are less than natural, due to water harvesting. High flows are also captured in storage.

Environmental flow recommendations are described below by reach and are summarised in Table 12. For Reaches 1 and 2, there were two conformance points – A and B. The environmental flow recommendations for conformance points A and B differ slightly, as the flow recommendations for the downstream site account for tributary inflows. The following descriptions are for conformance point A only, however conformance Point B environmental flow requirements are documented in Table 12.

Summer flow recommendations apply to the months of December to May, and winter flow recommendations apply to the months of June to November, unless otherwise indicated.

Reach 1 – Coliban River: Malmsbury Reservoir to Lake Eppalock

No cease-to-flow recommendations have been made for Reach 1.

- A **summer low flow** of 5 ML/day is recommended to maintain adequate habitat through the site. Summer low flow recommendations no longer contain the “or natural” clause in the case of Campaspe Reaches 1, 3 and 4, for reasons of water quality.

- **Summer freshes** of 100 ML/day, one per year for three days, duration are recommended to inundate vegetated benches, deliver organic matter into the stream and to aid fish movement. Summer freshes of 200 ML/day, one per year for three days duration, are recommended to scour algae and to maintain a thalweg in the channel.
- A **winter low flow** of 35 ML/day (or natural) is recommended for fish movement.
- **Winter freshes** of 700 ML/day, four per year for three days, are recommended to move sand, entrain organic matter and suppress encroaching terrestrial vegetation.
- A **winter bankfull** flow of 12,000 ML/day is recommended once every three years to entrain organic material, scour sediment and fine matter and break out to fill high flood runners (August to September).

Reach 2 – Campaspe River: Lake Eppalock to Campaspe Weir

No winter fresh recommendations have been made for Reach 2.

- A **summer cease to flow** event lasting fourteen days is recommended, for enhanced native fish recruitment (February to May).
- A **summer low flow** of 10 ML/day (or natural) is recommended, to fill the low flow channel. This flow should not be exceeded, to prevent the secondary channel from filling and promoting *Typha*.
- **Summer freshes** of 100 ML/day, up to three per year for five days, are recommended for fish movement.
- A **winter low flow** of 100 ML/day (or natural) is recommended for fish movement.
- A **winter high** flow of 1,000 ML/day, up to four per year for four days, is recommended to inundate benches.
- A **winter bankfull** flow of 10,000 ML/day lasting two days is recommended to mobilise sediments and scour stands of *Typha* (August to September).
- A **winter overbank** flow of 12,000 ML/day is recommended to wet most of the island at Doakes Reserve, connect flood runners, encourage River Red Gum regeneration and deliver a large load of organic material to the river (August).

Reach 3 – Campaspe River: Campaspe Weir to Campaspe Siphon

No summer cease to flow or winter fresh recommendations have been made for Reach 3.

- A **summer low flow** of between 10 and 20 ML/day is recommended to maintain flow through the reach, prevent further deterioration of water quality at the surface of pools and preserve backwater habitats for developing fish larvae and juvenile fish. Flows above 20 ML/day are not recommended as they will create too much flow through backwater habitats and decrease fish recruitment.
- **Summer freshes** of 100 ML/day, up to three per year for six days, are recommended to increase the wetted perimeter and maintain surface water quality.

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- A **winter low flow** of 200 ML/day is recommended to increase the wetted perimeter in the channel.
- A **winter high** flow of 1,500 ML/day, up to four per year for four days, is recommended to cover benches at mid-channel height and connect other in-channel features.
- A **winter bankfull** flow of 8,000 ML/day, up to two per year for two days, is recommended to fill the channel, mobilise sediment and help scour *Typha*.
- A **winter overbank** flow of 12,000 ML/day is recommended to promote regeneration of River Red Gum (August to September).

Reach 4 – Campaspe River: Campaspe Siphon to the River Murray

No summer cease to flow or winter fresh recommendations have been made for Reach 4.

- A **summer low flow** of between 10 and 20 ML/day is recommended to maintain flow and aquatic habitat. Summer low flows should not exceed 20 ML/day to ensure that backwater habitats for fish are preserved.
- **Summer freshes** of 100 ML/day, up to three per year for six days, are recommended to wet very low lying benches in the bottom of the channel (February to May).
- A **winter low flow** of 200 ML/day (or natural) is recommended to increase the wetted perimeter in the channel.
- A **winter high** flow of 1,500 ML/day, up to two per year for four days, is recommended to cover benches at mid-channel height and inundate all snags within the channel.
- A **winter bankfull** flow of 9,000 ML/day, up to two per year for two days, is recommended to mobilise sediment, scour *Typha* and flush organic matter into the stream.

Living Murray contribution

Preliminary Living Murray flow requirements assume that the Campaspe River could be called on to provide flows to Gunbower Forest, either as a routine flow over time, or as a short burst when a change in flow rate is needed. Flows could come from Lake Eppalock or Waranga Basin (via the Waranga Western Channel). To test limitations, it was assumed that a flow of up to 2,000 ML/day could be required between July and December. All Living Murray flow requirements are in addition to current flows and/or other environmental flow requirements.

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- **Table 12 Environmental flow recommendations for the Campaspe System (SKM, 2006).**

Season and Component	REACH NUMBER AND NAME											
	Reach 1			Reach 2			Reach 3		Reach 4		Living Murray contribution	
	Coliban River: Malmsbury Reservoir to Lake Eppalock *A – Lyal Road (main conformance point)* *B – Phillips Road (checking point U/S of A)*			*Campaspe River: Lake Eppalock to Campaspe Weir* *A – Doakes Reserve (main conformance point)* *B – English's Bridge (checking point D/S of At)*			*Campaspe River: Campaspe Weir to Campaspe Siphon*		*Campaspe River: Campaspe Siphon to the River Murray*		*Conformance assessed at Reach 4*	
	Rec. A	**Conform. A**	**Rec. B**	**Rec. A**	**Conform A**	**Rec. B**	**Rec.**	**Conformance**	**Rec.**	**Conformance**	**Rec**	**Comp**
SUMMER CEASE TO FLOW	Not recommended		Not recommended	**FEB to MAY** - 0 ML/d - 1 per year - for 14 days	Volume 10% Number 10% Duration 36%	**FEB to MAY** - 0 ML/d - 1 per year - for 14 days						
SUMMER LOW FLOW*	- 5ML/d - 1 per year - for 6 months	56% of days in period	- 2.5 ML/d - 1 per year - for 6 months	- 10 ML/d (or natural, should not exceed, for the control of typha) - 1 per year - for 6 months	Exceeded for 93% of days in period (i.e. 7% conformance)	- 16 ML/d (or natural) - 1 per year - for 6 months	- >10 and <20 ML/d - 1 per year - for 6 months	37% of days in period	- >10 and <20 ML/d - 1 per year - for 6 months	21% of days in period		
SUMMER FRESHES	- 100 ML/d <u>and</u> 200 ML/d - one of each per year - for 3 days - Rise 280% - Fall 65%	Volume 73% Number 39% Duration 42%	- 90 ML/d <u>and</u> 160 ML/d - One of each per year - for 3 days - Rise 280% - Fall 65%	- 100 ML/d - 3 per year (or natural) - for 5 days - Rise 230% - Fall 65%	Summer irrigation flows substantially higher	- 125 ML/d - 3 per year (or natural) - for 5 days - Rise 230% - Fall 65%	- 100 ML/d - 3 per year (or natural) - for 6 days - Rise 230% - Fall 65%	Nov to Dec flows lower than env. flow and Feb to May too high	**FEB to MAY** - 100 ML/d - 3 per year (or natural) - for 6 days - Rise 230% - Fall 65%	Volume 57% Number 6% Duration 38%		
WINTER LOW FLOW	- 35 ML/d (or natural) - 1 per year - for 6 months	48% of days in period	- 25 ML/d (or natural) - 1 per year - for 6 months	- 100 ML/d (or natural) - 1 per year - for 6 months	41% of days in period	- 120 ML/d (or natural) - 1 per year - for 6 months	- 200 ML/d (or natural) - 1 per year - for 6 months	31% of days in period	- 200 ML/day (or natural) - 1 per year - for 6 months	29% of days in period		
WINTER FRESHES	- 700 ML/d - 4 per year - for 3 days - Rise 280% - Fall 65%	Volume 85% Number 49% Duration 57%	- 560 ML/d - 4 per year - for 3 days - Rise 280% - Fall 65%									
WINTER HIGH FLOW				- 1,000 ML/d - 4 per year (or natural) - for 4 days - Rise 230% - Fall 65%	Volume 37% Number 3% Duration 83%	- 1,200 ML/d - 4 per year (or natural) - for 4 days - Rise 230% - Fall 65%	- 1,500 ML/d - 4 per year (or natural) - for 4 days - Rise 230% - Fall 65%	Volume 61% Number 22% Duration 43%	- 1,500 ML/day - 2 per year (or natural) - for 4 days - Rise 230% - Fall 65%	Volume 62% Number 50% Duration 42%	**JUL to DEC** - Low flow rec, plus 2,000 ML/d <u>Total = 2,200 ML/d</u> - as required to provide flows to Gunbower Forest	Volume 54% Number 1 event – 55% 2 events – 40% 3 events – 24% 4 events – 10% 5 events – 6% Duration 1 day – 100% 2 days – 77% 5 days – 35% 10 days – 20% 20 days – 10%
WINTER BANKFULL	**AUG to SEP** - 12,000 ML/d - 1 in 3 years - for 1 day - Rise 280% - Fall 65%	Volume 35% Number 35% Duration 100%	**AUG to SEP** - 6,000 ML/d - 1 in 3 years - for 1 day - Rise 280% - Fall 65%	**AUG to SEP** - 10,000 ML/d - 1 per year (or natural) - for 2 days - Rise 230% - Fall 65%	Volume 17% Number 17% Duration 100%	**AUG to SEP** - 12,000 ML/d - 1 per year (or natural) - for 2 days - Rise 230% - Fall 65%	- 8,000 ML/d - 2 per year (or natural) - for 2 days - Rise 230% - Fall 65%	Volume 17% Number 17% Duration 76%	- 9,000 ML/d - 2 per year (or natural) - for 2 days - Rise 230% - Fall 65%	Volume 17% Number 17% Duration 31%		
WINTER OVERBANK	As natural		As natural	**AUG** - 12,000 ML/d - 1 per year - for 1 day - Rise 230% - Fall 65%	Volume 6% Number 6% Duration 100%	**AUG** - 14,000 ML/d - 1 per year - for 1 day - Rise 230% - Fall 65%	**AUG to SEP** - 12,000 ML/d - 1 per year - for 1 day - Rise 230% - Fall 65%	Volume 19% Number 19% Duration 100%			**AUG to NOV** - Low flow rec, plus 20,000 ML/d from Goulb/Camp'pe <u>Total = 20,200 ML/d (a maximum flow of 2,000 ML/d is required from Campaspe River)</u> - as required to top up flood flows - for 1-2 months	Similar to winter high flow. Not assessed.

*Summer low flow recommendations no longer contain the "or natural" clause in the case of Campaspe Reaches 1, 3 and 4 (for reasons of water quality).

3.5.2 Conformance calculation method

Conformance with the current regime was assessed by SKM (2006) and is used herein. Modelled current and natural daily flow series for each environmental flow reach was used.

In the case of the Living Murray requirements, large flows could be required for extended periods to benefit downstream sites. These flows would be required on demand. That is, they could be called for at any time and in a period that does not necessarily correspond to a time of high flow in the Campaspe River. We cannot test to see if Living Murray requirements have been available historically on demand – because there has been no demand. What can be tested is whether flows of the specified magnitude and frequency have been recorded in the past and if not, why not? For example, are there structural or operational constraints that restrict the volume of water that can be delivered to the lower reaches of the Campaspe River?

3.5.3 Conformance results

Cease to flow

An annual cease to flow event is recommended for Reach 2. However, cease to flow conditions are experienced at a frequency of only one year in ten. Only a third of cease to flow events exceed 14 days.

Summer low flow

Summer low flow conformance varies considerably across the four environmental flow reaches. The Campaspe Bulk Entitlement (BE) specifies that there must be an 8 ML/day, or natural, passing flow below Malmsbury Reservoir, whichever is lesser. This condition has been applied since 2000 and has been built into the REALM model used to model flows in the Campaspe River. However, in Reach 1 below Malmsbury Reservoir, the low flow requirement (>5 ML/day or natural) is achieved in only approximately half of the days within the period due to the considerable losses within this reach.

In Reach 2, the recommended summer low flow is exceeded in the majority of days due to irrigation releases from Lake Eppalock.

In Reach 3 under current conditions, the summer low flow range of 10-20 ML/day is only met 37% of the time. Current flows through this reach are less than the recommended summer low flow for much of the time between December and February, but exceed the recommended flow in autumn when irrigation transfer flows are delivered to the Campaspe Siphon.

In Reach 4, the summer low flow conformance is similarly poor. Flows in this reach frequently exceed the 20 ML/day recommended maximum.

Summer freshes

In Reaches 1 and 4, summer fresh volumes are achieved in 73% and 57% of years, respectively. However, the number and duration of summer freshes is less than recommended. In Reach 2, irrigation deliveries below Lake Eppalock and Campaspe Siphon mean that flow is substantially higher than the summer fresh volume.

Winter low flow

In all reaches there is low conformance with the winter low flow volume. Water is harvested in the winter months, meaning that flow is consistently lower than recommended.

Winter freshes

Winter freshes are only specified for Reach 1. In this reach, the fresh volume is frequently achieved. However, the frequency and duration of freshes is less than recommended.

Winter high flow

Lake Eppalock is used for water harvesting for irrigation. Hence the winter high flow conformance in Reach 2 is poor. The winter high flow conformance improves downstream of Lake Eppalock, possibly due to the effects of tributary inflows.

Winter bankfull flow

The recommended frequency of a winter bankfull flow event is one every three years for Reach 1, one per year for Reach 2 and one every two years for Reaches 3 and 4. However, the current frequency of bankfull flow events is much lower than this under current system operation.

Winter overbank flow

Similarly, winter overbank flow events in Reaches 2 and 3 occur at a frequency that is considerably less than recommended.

Living Murray

The Campaspe River and the Goulburn River could be required to provide 20,000 ML/day (total) for one to two months at a time. Flows of 20,000 ML/day are recorded in the Campaspe River in approximately one year in five. However such events do not last for more than three days at a time. Flows exceeding 2,000 ML/day are more frequent and persist for longer periods of time.

3.6 Birches and Tullaroop Creeks

Birches and Tullaroop Creeks are located in the upper reaches of the Loddon River. A study by SKM investigated environmental flow recommendations for Birches Creek and Tullaroop Creek above Tullaroop Reservoir (SKM, 2005a; 2005b). SKM divided the study area into four environmental flow reaches:

- Reach 1 – Birches Creek: Newlyn Reservoir to the confluence with Hepburn Race;

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- Reach 2 – Birches Creek: Hepburn Race to Lawrence weir;
- Reach 3 – Birches Creek: Lawrence weir to the confluence with Creswick Creek; and
- Reach 4 – Tullaroop Creek: Creswick Creek confluence to Tullaroop Reservoir.

The study of Loddon River environmental flows also investigated environmental flow recommendations for Tullaroop Creek, from Tullaroop Reservoir to Laanecoorie Reservoir (Loddon River Environmental Flows Scientific Panel, 2002). This reach is examined in the following section, which covers environmental flow recommendations for the Loddon River (Section 3.7)

3.6.1 Environmental flow recommendations

Both Birches and Tullaroop Creek are highly regulated. Water is harvested from these streams in the winter months and released for irrigation supply in the summer. There are no cease to flow recommendations for Birches and Tullaroop Creeks. Environmental flow recommendations are described below by reach and are summarised in Table 13 .

Reach 1 – Newlyn Reservoir to the confluence with Hepburn Race

Reach 1 is directly downstream of Newlyn Reservoir and, as such, flows in this reach are highly regulated:

- A **summer low** flow of 3 ML/day (or natural) is recommended to maintain adequate habitat throughout the site to ensure the survival of aquatic biota.
- **Summer freshes** of 10 ML/day, up to four per year for three days, are recommended to flush medium sand and silt and to improve water quality by flushing and turning over pools.
- A **winter low** flow of 10 ML/day (or natural) is recommended to wet small side channels and to sustain flow over riffles.
- **Winter freshes** of 40 ML/day, up to three per year for five days, are recommended to inundate the entire channel bottom, aggraded flats and islands in the middle of the channel.
- A winter **high flow** of 160 ML/day, up to three per year for five days, is recommended to almost fill the entire main channel and provide more depth in the smaller channels and aggraded flats.

Reach 2 – Hepburn Race to Lawrence weir

- A **summer low** flow of 5 ML/day (or natural) has been recommended to maintain adequate habitat throughout the site to ensure the survival of aquatic biota.
- **Summer freshes** of 15 ML/day, up to four per year for three days, have been recommended to increase depth in the riffles and wet emergent and marginal aquatic vegetation.
- A **winter low** flow of 10 ML/day (or natural) has been recommended to increase riffle width.
- **Winter freshes** of 55 ML/day, up to three per year for five days, have been recommended for bench inundation and organic cycling.
- A **winter high** flow of 275 ML/day, up to two per year for three days, has been recommended to provide more depth in the pools and provide lateral connectivity between the stream and high flow channels.

SKM

Reach 3 – Lawrence weir to the confluence with Creswick Creek

- A **summer low** flow of 8 ML/day (or natural) has been recommended to maintain adequate habitat throughout the site to ensure the survival of aquatic biota.
- **Summer freshes** of 27 ML/day, up to four per year for four days, have been recommended to expand riffle/run areas and to enhance connectivity between pools for fish movement.
- A **winter low** flow of 20 ML/day (or natural) has been recommended to wet smaller side channels and benches.
- **Winter freshes** of 65 ML/day, up to three per year for five days, have been recommended to inundate the channel bottom and islands in the middle of the channel.
- A **winter high** flow of 200 ML/day, up to three per year for three days, has been recommended to provide more depth in the pools and over benches, provide lateral connectivity between the streams, provide high flow channels throughout the reach and flush leaf litter from benches.
- A **winter overbank** flow event of 1,300 ML/day is recommended to act as an ecosystem disturbance.

Reach 4 – Creswick Creek confluence to Tullaroop Reservoir

No winter high flow recommendations have been made for Reach 4:

- A **summer low** flow of 10 ML/day (or natural) has been recommended to maintain adequate habitat throughout the site to ensure the survival of aquatic biota.
- **Summer freshes** of 23 ML/day, up to four per year for seven days, have been recommended to scour and prevent the excessive accumulation of bio-film and sediment on the streambed.
- A **winter low** flow of 16 ML/day (or natural) has been recommended to inundate the majority of the lower channel features and riffles.
- **Winter freshes** of 250 ML/day, up to three per year for five days, have been recommended to inundate the channel bottom.
- A **winter overbank** flow event of 2,580 ML/day is recommended to act as an ecosystem disturbance.

Table 13 Environmental flow recommendations for Birches and Tullaroop Creeks (SKM, 2005a; 2005b).

Season and Component	REACH NUMBER AND NAME							
	Reach 1		Reach 2		Reach 3		Reach 4	
	Birches Creek: Newlyn Reservoir to Hepburn Race		*Birches Creek: Hepburn Race to Lawrence weir*		*Birches Creek: Lawrence weir to Creswick Creek confluence*		*Tullaroop Creek: Creswick Creek confluence to Tullaroop Reservoir*	
	Rec	**Conformance**	**Rec**	**Conformance**	**Rec**	**Conformance**	**Rec**	**Conformance**
SUMMER LOW FLOW	- 3 ML/d (or natural) - 1 per year - for six months	65% of days in period	- 5 ML/d (or natural) - 1 per year - for 6 months	58% of days in period	- 8 ML/d (or natural) - 1 per year - for 6 months	36% of days in period	- 10 ML/d (or natural) - 1 per year - for 6 months	45% of days in period
SUMMER FRESHES	- 10 ML/d, - 4 per year (or natural), - for 3 days	Volume 75% Number 32% Duration 35%	- 15 ML/d - 4 per year (or natural) - for 3 days	Volume 70% Number 13% Duration 50%	- 27 ML/d - 4 per year (or natural) - for 4 days	Volume 55% Number 6% Duration 30%	- 23 ML/d - 4 per year (or natural) - for 7 days	Volume 80% Number 27% Duration 40%
WINTER LOW FLOW	- 10 ML/d (or natural), - 1 per year - for 6 months	62% of days in period	- 10 ML/d (or natural) - 1 per year - for 6 months	76% of days in period	- 20 ML/d (or natural) - 1 per year - for 6 months	66% of days in period	- 16 ML/d (or natural) - 1 per year - for 6 months	86% of days in period
WINTER FRESHES	- 40 ML/d - 3 per year (or natural) - for 5 days	Volume 85% Number 33% Duration 65%	- 55 ML/d - 3 per year (or natural) - for 5 days	Volume 90% Number 33% Duration 60%	- 65 ML/d - 3 per year (or natural) - for 5 days	Volume 90% Number 26% Duration 70%	- 250 ML/d - 3 per year (or natural) - for 5 days	Volume 85% Number 55% Duration 60%
WINTER HIGH	- 160 ML/d - 3 per year (or natural) - for 5 days	Volume 70% Number 50% Duration 50%	- 275 ML/d - 2 per year (or natural) - for 3 days	Volume 70% Number 76% Duration 65%	- 200 ML/d - 3 per year (or natural) - for 3 days	Volume 75% Number 45% Duration 75%		
WINTER BANKFULL					- 1,300 ML/d - 1 per year (or natural) - for 1 day	Volume 35% Number 63% Duration 100%	- 2,580 ML/d - 1 per year (or natural) - for 1 day	Volume 40% Number 69% Duration 100%

SKM

3.6.2 Conformance calculation method

The authors of the Birches Creek environmental flows study used modelled current and natural daily flow series for each environmental flow reach to assess environmental flow conformance (SKM, 2005). The current flow series is the flow regime that refers to the full uptake of licence volumes and not the current metered usage. The natural flow series is the flow regime that would exist if no diversion or storage of water occurred, but accepting that there have been no increases in flows due to vegetation removal or landuse.

Currently, there is a requirement to comply with the Loddon Environmental Reserve BE for the Tullaroop reach (see also Section 3.7.2).

3.6.3 Conformance results

Summer low flows

In Birches Creek and Tullaroop Creek above Tullaroop Reservoir the summer low flow conformance is poor, frequently falling below the summer minimum.

Summer freshes

The summer fresh volume is often achieved in Birches Creek and Tullaroop Creek above Tullaroop Reservoir. However, the frequency and duration of events is less than natural due to a lack of variability in the flow regime.

Winter low flows

The winter low flow requirement is met for more than half of the days in the winter period.

Winter freshes

The winter fresh volume is often achieved in Birches Creek and Tullaroop Creek above Tullaroop Reservoir. However, the frequency of events is less than recommended due to a lack of variability in the flow regime.

Winter/Anytime high flows

Similarly, the winter high flow volume is often achieved in all reaches (excluding Reach 4, which does not have a high flow requirement). However, the number and/or duration of high flows are commonly less than recommended.

Winter bankfull flow

A winter bankfull flow is recommended for Reach 3 (Birches Creek: Lawrence weir to the confluence with Creswick Creek) and Reach 4 (Tullaroop Creek: Creswick Creek confluence to Tullaroop Reservoir). These winter bankfull flows are recommended to occur at a frequency of one per year. The current frequency under regulated conditions is approximately one every three years.

3.7 Loddon River

The Loddon Scientific Panel divided the Loddon River below Cairn Curran Reservoir, and Tullaroop Creek from Tullaroop Reservoir to Laanecoorie Reservoir, into six environmental flow reaches, namely:

- Reach 1 – Loddon River: Cairn Curran Reservoir to Laanecoorie Reservoir;
- Reach 2 – Tullaroop Creek: Tullaroop Reservoir to Laanecoorie Reservoir.
- Reach 3a – Loddon River: Laanecoorie Reservoir to Serpentine Weir;
- Reach 3b – Loddon River: Serpentine Weir to Loddon Weir;
- Reach 4 – Loddon River: Loddon Weir to Kerang Weir; and
- Reach 5 – Loddon River: Kerang Weir to River Murray.

The conformance point for Living Murray contributions has not been specified. However, as these recommendations assume that flow will be delivered to the River Murray it is assumed that the conformance point is (or is downstream of) Reach 5.

3.7.1 Environmental flow recommendations

The Loddon River is highly regulated. Water is harvested in winter months, meaning that winter flows are less than natural. During summer months water is released from storage to supply irrigators. Hence summer flows are higher than natural and lack the variability of the natural flow regime.

Many of the environmental flow recommendations developed by the Loddon Scientific Panel (2002) are designed to provide variation to the flow regime and in some instances, to restore flow to within a range of volumes that would have been experienced naturally. Environmental flow recommendations are described below by reach and are summarised in Table 14 .

Reach 1 – Cairn Curran Reservoir to Laanecoorie Reservoir

Reach 1 is directly downstream of Cairn Curran Reservoir and, as such, flows in this reach are highly regulated:

- A **cease-to-flow** event is recommended on the proviso that higher flows are provided to reinstate the pool structure within the reach
- A **summer low flow** of >20 ML/d (or natural) is recommended for the preservation of fish species (November to April).
- **Summer freshes** of >35 ML/day, three per year for seven days, are recommended for fish movement and for scouring deposited sediment off the stream bed (November to April).
- A **winter low flow** of >35 ML/day (or natural) is recommended for fish movement (May to October).
- **Winter freshes** of >181 ML/day, three per year for twenty-five days, are recommended for stream bed maintenance and bank vegetation (May to August).

- A **winter high** flow of 3,000 ML/day, one in four years for four days, is recommended for Murray cod and Golden perch breeding (August to November).
- A **winter overbank** flow event of >3,000 ML/day, one per year for four days, is recommended to entrain organic material such as River Red Gum leaves and twigs (June to August).
- An **anytime high** flow of 3,000 ML/day, one per year for four days, is recommended to restore the pool structure of the reach.

Reach 2 – Tullaroop Creek: Tullaroop Reservoir to Laanecoorie Reservoir

- A **low flow** of >10 ML/d (or natural) is recommended to maintain habitat for River blackfish populations (all year).
- **Summer freshes** of >13.5 ML/day, four per day for seven days, are recommended to scour excess silt from the bed surface (November to April).
- **Winter freshes** of >132 ML/day, two per year for seven days, are recommended for fish movement (May to August).
- A **winter high** of 500 ML/day, two per year (four years in five) for four days, is recommended to inundate benches and sweep organic material into the stream (August to November).
- An **anytime high** of 500 ML/day, one per year (four years in five) for four days, is recommended to maintain disturbance related processes.
- An **anytime high** flow of 3,000 ML/day, one year in two, is recommended for geomorphic functions.

Reach 3a – Laanecoorie Reservoir to Serpentine Weir

There is no cease-to-flow environmental flow recommendation for Reach 3a:

- A **summer low flow** of >15 ML/d (or natural) is recommended for plant re-establishment (November to July).
- **Summer freshes** of >52 ML/day, three per year for thirteen days, are recommended for fish movement (November to April).
- A **winter low flow** of >52 ML/day is recommended for fish movement (August to October).
- **Winter freshes** of >900 ML/day, two per year for nine days, are recommended to maintain habitat quality in pools and runs, and to inundate low level benches in the river (August to October).
- A **winter high** flow of 7,300 ML/day, one in two years for one day, is recommended to inundate high level benches to entrain organic material and maintain the channel form and complexity (June to October).

Reach 3b – Serpentine Weir to Loddon Weir

- A **summer low flow** of >19 ML/d (or natural) is recommended to preserve natural low flow shallow water conditions (November to April).
- **Summer freshes** of >61 ML/day, three per year for eleven days, are recommended for fish movement and habitat maintenance (November to April).

- A **winter low flow** of >61 ML/day is recommended for fish movement (May to October).
- **Winter freshes** of >400 ML/day, two per year for seven days, are recommended for low bench inundation (August to October).
- A **winter high** flow of >2,000 ML/day, two per year for six days, is recommended for high bench inundation and to maintain pool conditions through scour (August to October).
- A **winter overbank** flow event of >13,000 ML/day, one in three years for two days, is recommended for red-gum regeneration and geomorphic functions (June to October).

Reach 4 – Loddon Weir to Kerang Weir

Cease-to-flow recommendations for Reach 4 are yet to be determined due to a lack of information:

- A **summer low flow**, varied between 7 and 12 ML/d, is recommended for fish movement (November to April).
- **Summer freshes** of >50 ML/day, one per year for fourteen days, are recommended to provide an attracting flow for Golden perch from Kerang Weir (January to February).
- A **winter low flow** of >61 ML/day is recommended for fish habitat (May to October).
- A **winter overbank** flow event of >400 ML/day, two per year for seven days, is recommended for geomorphic functions (July to October).

Reach 5 – Kerang Weir to River Murray

Due to a lack of data, most of the environmental flows for Reach 5 are formulated to preserve the environmental flows from Reach 4. The environmental flow recommendation (that is in addition to the above recommendation for Reach 4) is:

- A **winter overbank** flow event of >1,200 ML/day, two per year for seven days, is recommended for geomorphic functions (July to October).

Living Murray contribution

Preliminary Living Murray flow requirements assume that the Loddon River may be called upon to provide a steady flow to the River Murray to benefit iconic sites downstream. To assess potential constraints to the delivery of such a flow, it was assumed that 500 ML/day could be required in any month of the year, for one to two months duration.

Table 14 Environmental flow recommendations for the Loddon River below Cairn Curran Reservoir (Loddon River Environmental Flows Scientific Panel, 2002).

Season and Component	REACH NUMBER AND NAME													
	Reach 1		Reach 2		Reach 3a		Reach 3b		Reach 4		Reach 5		Living Murray contribution	
	Loddon River: Cairn Curran Reservoir to Laanecoorie Reservoir		*Tullaroop Creek: Tullaroop Reservoir to Laanecoorie Reservoir*		*Loddon River: Laanecoorie Reservoir to Serpentine Weir*		*Loddon River: Serpentine Weir to Loddon Weir*		*Loddon River: Loddon Weir to Kerang Weir*		*Loddon River: Kerang Weir to the River Murray*		*Conformance assessed at Reach 5*	
	Rec	Conformance	Rec	Conformance	Rec	Conformance	Rec	Conformance	Rec	Conformance	Rec	Conformance	Rec	Comp
CEASE TO FLOW	- 0 ML/d - 1 in 4 years - for 2 months	Volume 0% Number 0% Duration 0%							To be determined		To be determined			
SUMMER LOW FLOW	- >20 ML/d (or natural) - annually - **Nov to Apr**	95% of days in period	- >10 ML/d (or natural) - annually - **all year**	100% of days in period	- >15 ML/d (or natural) - annually - **Nov to Jul**	99% of days in period	- >19 ML/d (or natural) - annually - **Nov to Apr**	84% of days in period	- >7 and <12 ML/d (variable min) - annually - **Nov to Apr**	87% of days in period	- >7 and <12 ML/d (variable min) - annually - **Nov to Apr**	3% of days in period		
SUMMER FRESHES	**NOV-APR** - >35 ML/d - 3 per year - for 7 days	Volume 100% Number 8% Duration 97%	**NOV-APR** - >13.5 ML/d - 4 per year - 7 days	Volume 100% Number 0% Duration 96%	**NOV-APR** - >52 ML/d - 3 per year - for 13 days	Volume 100% Number 4% Duration 90%	**NOV-APR** - >61 ML/d - 3 per year - for 11 days	Volume 96% Number 44% Duration 63%	**JAN-FEB** - >50 ML/d - 1 per year - for 14 days	Volume 8% Number 8% Duration 0%	**JAN-FEB** - >50 ML/d - 1 per year - 14 days	Volume 92% Number 92% Duration 45%		
SUMMER HIGH													NOV-APR - Low flow requirement, plus 500 ML/d. <u>Total = 510 ML/d</u> - as required in any month - for 1 to 2 months	Volume 96% Number I event - 92% 2 events - 64% 3 events - 24% Duration 30 days - 13% 45 days - 4% 60 days - 4%
WINTER LOW FLOW	- >35 ML/d (or natural) - annually - **May to Oct**	38% of days in period	- >10 ML/d (or natural) - annually - **all year**	100% of days in period	- >52 ML/d - annually - **Aug to Oct**	89% of days in period	- >61 ML/d - annually - **May to Oct**	61% of days in period	- >61 ML/d - annually - **May to Oct**	37% of days in period	- >61 ML/d - annually - **May to Oct**	99% of days in period		
WINTER FRESHES	**MAY–AUG** - >181 ML/d - 3 per year - for 25 days	Volume 48% Number 0% Duration 42%	**MAY–AUG** - >132 ML/d - 2 per year - for 7 days	Volume 28% Number 0% Duration 57%	**AUG-OCT** - >900 ML/d - 2 per year - 9 days	Volume 88% Number 56% Duration 30%	**AUG-OCT** - >400 ML/d - 2 per year - for 7 days	Volume 92% Number 64% Duration 50%						
WINTER HIGH	**AUG–NOV** - 3,000 ML/d - 1 in 4 years - for 4 days	Volume 100% Number 100% Duration 40%	**MAY-AUG** - 500 ML/d - 2 per year, 4 years in 5 - for 4 days	Volume 16% Number 5% Duration 80%	**JUN-OCT** - 7,300 ML/d - 1 in 2 years - for 1 day - Natural rates of rise and fall	Volume 100% Number 100% Duration 100%	**AUG-OCT** - >2,000 ML/d - 2 per year - for 6 days	Volume 72% Number 44% Duration 49%			**JUL-OCT** - >400 ML/d - 2 per year - for 7 days	Volume 100% Number 64% Duration 75%	MAY-OCT - Low flow requirement, plus 500 ML/d. <u>Total = 561 ML/d</u> - as required in any month - for 1 to 2 months	Volume 100% Number I event - 100% 2 events - 88% 3 events - 68% Duration 30 days - 23% 45 days - 19% 60 days - 14%
OVERBANK	**JUN-AUG** - >3,000 ML/d - 1 per year - for 4 days	Volume 24% Number 24% Duration 38%					**JUN-OCT** - >13,000 ML/d - 1 in 3 years - for 2 days - Natural rates of rise and fall	Volume 0%* Number 0%* Duration 0%* (see note below)	**JUL-OCT** - >400 ML/d - 2 per year - for 7 days	Volume 44% Number 44% Duration 47%	**JUL-OCT** - >1200 ML/d - 2 per year - for 7 days	Volume 100% Number 68% Duration 72%		
ANYTIME HIGH	- 3,000 ML/d - 1 per year - for 4 days	Volume 52% Number 52% Duration 30%	- 500 ML/d - 1 per year, 4 years in 5 - for 4 days	Volume 100% Number 100% Duration 43%										
			- 3,000 ML/d - 1 in 2 years - for 1 day - Natural rates of rise and fall	Volume 64% Number 64% Duration 100%										

NB: The seasons don't necessary fall neatly into the categories of "winter" and "summer", but environmental flow component have been grouped under these headings. Hence the applicable months have been specified in bold type.

*Scientific Panel asserts that overbank flow recommendation is currently achieved 9 years in 27, 2 days duration. Scientific Panel used gauged record at 407229 (Loddon River at Serpentine Weir) for conformance calculations. We have used modelled REALM data for a downstream location.

3.7.2 Conformance calculation method

To date the implementation of environmental flow recommendations in the Loddon River has been limited to the provision of summer low flows (not Reach 5) and summer freshes in Reach 4. Also, there is a requirement to comply with the environmental flow recommendations provided in the Loddon Environmental Reserve BE. This includes minimum passing flows and river freshening flows:

> The passing flows and river freshening flows "are based on the recommendations of the Environmental Flow Determination (EFD)….although "or natural" provisions are provided in the Environmental Reserve BE for some flows where they are not specifically recommended in the EFD. It should also be noted that the Environmental Reserve BE does not provide enough water for all the recommended flows through some are achieved through irrigation releases, and some are "over-achieved" through irrigation releases although a maximum flow in ML/d is not specified in the EFD nor the Environmental Reserve BE." (*pers. comm.,* Catherine Fox and Kathryn Stansilawski, NCCMA, 11-Aug-2006)

Conformance to the environmental flow recommendations summarised herein was calculated for all defined flow requirements in order to identify constraints for the delivery of environmental flows. Environmental flow conformance in the Loddon River was assessed using 25 years of modelled flow data representing both the natural and current level of development. The modelled natural flow data was the same as that used by the Loddon Scientific Panel, but the Panel used gauged flow in place of modelled "current" data. For this reason, the conformance results reported herein differ slightly to the conformance results documented by the Loddon Scientific Panel (2002).

3.7.3 Conformance results

Cease-to-flow

The current operation of the system does not provide for cease-to-flow events in Reach 1.

Summer low flows

Due to releases for irrigation deliveries, summer low flows are exceeded in the majority of days in the summer period in Reaches 1, 3a and 3b (Cairn Curran Reservoir to Loddon Weir). Similarly, the summer low flow conformance is very high in Reach 2 (Tullaroop Creek, between Tullaroop Reservoir and Laanecoorie Reservoir) due to the (modelled) release of water from Tullaroop Reservoir. The Loddon Scientific Panel (2002), however, asserts that the low flow requirement in this reach is not achieved because summer flows are well in excess of the low flow recommendation.

In Reach 4 a summer maximum, as well as a summer minimum, is recommended. Conformance in this reach is 87% due to the (modelled) operation of the Loddon Weir. In Reach 5 conformance is only 3%. In the past, flows below Kerang Weir have been discharged at the rate of 100 ML/day to supply private diverters in this reach. This passing flow is featured in the REALM model for the Loddon River but is often superseded by other system requirements.

Summer freshes

The summer fresh volume is often achieved in Reaches 1, 3a and 3b as irrigation releases are within the range of fresh volumes. However, the frequency of events is less than natural due to a lack of variability in the flow regime. Similarly, in Reach 2 (Tullaroop Creek, between Tullaroop Reservoir and Laanecoorie Reservoir), summer releases exceed the summer fresh volume, resulting in high flows of an extended duration, but the recommended number (four per year) is never achieved. Conformance in Reach 4 is very poor, but the frequency and number of summer freshes in Reach 5 is close to recommended.

Winter low flows

Winter low flow conformance varies between reaches. Due to water harvesting, winter low flow conformance below Cairn Curran Reservoir (Reach 1) is only 38%. Conformance below Loddon Weir (Reach 4) is also poor. In Reaches 2, 3a, 3b and 5, the winter low flow is achieved in the majority of days during the winter period.

Winter freshes

Winter fresh conformance in Reach 1 is poor. The fresh volume is only achieved every second year and never at a rate of three events per year. In Reach 2 (Tullaroop Creek between Tullaroop Reservoir and Laanecoorie Reservoir) the winter fresh conformance is similarly poor. In Reaches 3a and 3b the fresh volume is often achieved. However, river regulation means that the number and duration of winter freshes is less than recommended.

Winter high flows

The winter high flow requirement varies greatly depending on the reach in question. The winter high flow conformance in generally good, except in Reach 2, where high flows are captured in Tullaroop Reservoir.

Winter overbank flows

Similarly, the winter overbank requirement varies greatly, depending on the reach in question. There is low conformance in Reach 1 (below Cairn Curran Reservoir) and Reach 4 (below Loddon Weir).

The modelled current flow series that has been used to represent flow in Reach 3b never reaches the overbank flow requirement of 13,000 ML/day. However, the Loddon Scientific Panel asserts that overbank flow recommendation is currently achieved 9 years in 27. The Loddon Scientific Panel used gauged record at 407229 (Loddon River at Serpentine Weir) for conformance calculations. Modelled REALM data for a downstream location has been used for the present study. The Loddon Scientific Panel has examined recorded data and have found that “all flow in excess of 9,900 ML/day spills out of the main Loddon channel between Serpentine Weir and Loddon Weir” (Loddon River Environmental Flows Scientific Panel, 2002b, p. 28) thus explaining the discrepancy.

Living Murray

Currently flows in the Loddon River frequently reach 500 ML/day. However, few events last longer than 30 days. This assessment was made without consideration of the timing of flows.

3.8 Summary

In all reaches of the Goulburn River, the frequency of overbank events is less than natural and less than recommended. However flow events of the magnitude required to fulfil Living Murray requirements are frequently experienced.

The Steering Committee has specified minimum flows for Broken Creek for the purpose of keeping fish ladders open, to minimise Azolla accumulation and to manage dissolved oxygen. These minimum flows occur in the majority of days during the specified months. Fresh flows for flushing Broken Creek in response to rapid Azolla blooms occur in nearly 90% of years, but it is not known whether fresh flows occur at the same time as Azolla blooms.

There is a significant flow inversion in the Campaspe River downstream of Lake Eppalock, Loddon River between Cairn Curran Reservoir and Loddon Weir and downstream of Kerang Weir, and Tullaroop Creek downstream of Tullaroop Reservoir, with water being harvested in the winter months and released in the summer for irrigation supply. In most cases, river regulation has removed the natural flow variation from the system. Often the summer and winter fresh volumes are being met but the recommended number and duration are not.

4. Goulburn and Broken Systems – Constraints and Options

4.1 Introduction

This Chapter provides an overview of the operational and infrastructure constraints associated with the delivery of the recommended environmental flows in the Goulburn River and Broken Creek. For the purposes of the study, a constraint is defined as any infrastructure limitation or operational requirement that would currently prevent the recommended environmental flow regime from being delivered. It should be recognised that in many cases, despite there being no constraints to the delivery of a particular recommended environmental flow regime component (viz summer low flows, winter freshes, etc), it is not currently being delivered simply because there is no requirement to do so. Constraints are summarised in Table 16, and discussed further in Section 4.2.

This Chapter also lists a range of options for the delivery of each of the recommended environmental flow regime components in each reach. If recommended flow components are the same or similar in adjacent reaches, then these reaches have been combined for the purposes of option development. Options are summarised in Table 16, and further details are provided in Appendix G and Appendix H.

It should be noted that in this Chapter, options have been developed for the delivery of each environmental flow regime component for the particular reach in which the component has been recommended. Many of these options will also impact on delivery of other recommended flow components within the same reach, and on the same and other flow components in other reaches. These interactions, and similar interactions associated with combinations of options, are identified and assessed in Chapters 8 and 9.7.

4.2 Constraints

4.2.1 Goulburn River

The major constraint to the delivery of summer low flows to the Goulburn River between Eildon and Goulburn Weir is the need to supply peak irrigation demands, via the River, during the irrigation season. These peak demands, typically of the order of 10,000 ML/d, are significantly greater than the recommended maximum summer low flows of between 1,400 and 3,000 ML/d. The following factors dictate the need to supply relatively constant peak irrigation demands during the irrigation season:

- there is relatively little active storage available at Goulburn Weir, and Goulburn Weir must be maintained at a relatively constant level during the irrigation season, close to crest level, to enable flows to be delivered to the Stuart Murray Canal, Cattanach Canal and East Goulburn Main Channel at the rates required to satisfy irrigation demands;

- the capacities of the Stuart Murray, Cattanach and East Goulburn Main Channels are only just sufficient to enable them to meet required irrigation demands;
- relatively high levels must be maintained in the Stuart Murray Canal during the irrigation season to enable it to deliver peak irrigation flows into Central Goulburn channels between Goulburn Weir and Waranga Basin;
- there is no storage along the East Goulburn Main Channel;
- The recommended low flows cannot be released for short periods, and high flows then released for similarly short periods to compensate, as releases from Eildon in excess of 14,500 ML/d result in nuisance flooding in the vicinity of Molesworth and Thornton (see further below). Any rapid changes to flows are also currently restricted to avoid bank erosion and slumping along the Goulburn River.

Delivery of the recommended spring overbank flow regime is currently constrained by potential flood impacts. Flows at which flooding of various severity occurs are presented in Table 15. Flows in excess of around 14,500 ML/d cause nuisance flooding around Molesworth and the township of Thornton. Much larger flows (in excess of 40,000 ML/d) are required to cause more significant flood impacts such as damage to residential properties.

Table 15 Goulburn River Flood flows

Station	Station Name	Minor Flood[1] (ML/d)	Moderate Flood[2] (ML/d)	Major Flood[3] (ML/d)
405203	Goulburn R at Lake Eildon	14,500	26,000	40,000
405201	Goulburn R at Trawool	21,700	41,500 *	83,000
405202	Goulburn R at Seymour	22,800	38,900 *	80,900 *
405200	Goulburn R at Murchison	29,200	58,800	79,670
405204	Goulburn R at Shepparton	22,500	67,780	87,000
405232	Goulburn R at McCoys Bridge	29,200	50,000	62,600 *

* *linear interpolation*

[1]***Minor Flooding***. *Causes inconvenience. Low lying areas next to watercourses are inundated requiring the removal of stock and equipment. Minor roads may be closed and low level bridges submerged.*

[2]***Moderate Flooding***. *In addition to the above, may require the evacuation of some houses. Main traffic routes may be covered. The area of inundation is substantial in rural areas.*

[3]***Major Flooding***. *In addition to the above, causes inundation of extensive rural areas and appreciable urban areas. Properties and towns are likely to be isolated and major traffic routes likely to be closed. Numerous evacuations may be required*

Eildon is also currently operated in accordance with rules linked to target filling curves and flood mitigation requirements. These rules are linked to the current Bulk Entitlement, and this would need to be amended if the current operational rules were to be changed.

It should be noted that there are no infrastructure constraints to the delivery of the recommended environmental flow regimes in the Goulburn River. Releases of up to around 20,000 ML/d, which is the order of magnitude of release required to meet recommended spring overbank and Living Murray winter fresh requirements, can still be made from Eildon at a level corresponding to only 10% of storage capacity.

4.2.2 Broken Creek

Delivery of the constant flows recommended to keep fish ladders open (30-40 ML/d) and minimise Azolla accumulation (80-140 ML/d), throughout the irrigation season, is currently constrained by a lack of available channel capacity. Channel capacity is usually committed to supplying peak irrigation demands, and no additional flows are then available to outfall to Broken Creek. Delivery of this flow has sometimes been constrained by the limited ability of current infrastructure to control low flows along Broken Creek. Channel operators have generally overcome this issue by operating lesser numbers of gates. Lack of low flow control is often exacerbated by uncertainties in travel times and difficulties in predicting irrigator orders. It could take as long as 11 days for flow to travel from Katamatite to Rice's Weir. G-MW has recently introduced water ordering and central planning for the Broken Creek diverters and they are closely monitored to ensure unauthorised extractions are minimised.

Lack of available channel capacity also constrains the ability to deliver the flows required at short notice to provide flushing of Broken Creek following an Azolla bloom. Delivery of these flushing flows is additionally constrained by long travel times along irrigation channels and along the Creek itself. Deliveries from both Murray and Goulburn systems could take around 4 and 7 days respectively to reach Broken Creek.

▪ Table 16 Goulburn and Broken System Constraints and Options

Reach	Season	Summary of Current conformance	Constraints/Reasons		Options
			Operational	Infrastructure	
Goulburn River – Eildon to Goulburn Weir/ Nagambie (Reaches 1,2 and 3)	Summer	<u>Summer Low</u> 6-31% of days in period meet recommended flows. Recommended maximum low flows range from 1,400 to 3,000 ML/d. Typical current flows are of the order of 10,000 ML/d	Need to supply irrigation demands to irrigation districts and other demand centres from Eildon (also reflected in Eildon operational rules - target filling curves) Damage to river banks due to rapid rise and fall limit summer flow variability Potential to flood Thornton and low lying land at Molesworth prevents large summer flow variability that would increase peak flows above 14,500 ML/d (also reflected in Eildon operational rules for flood mitigation)	No infrastructure constraints	▪ G1S1 - Pipeline from Eildon to Goulburn Weir ▪ G1S2a - Pulse flows from Eildon – large amplitude ▪ G1S2b - Pulse flows from Eildon – small amplitude ▪ G1S3 - Modified operation of Waranga Basin ▪ G1S4 - Divert flows from Broken River into EGM ▪ G1S5 - On-stream storage at Camp Hill ▪ G1S6 - Enlarge Waranga Basin ▪ G1S7 - On-farm and regional winter fill storages ▪ G1S8 - Use of Lake Cooper ▪ G1S9 - New Storage along East Goulburn Main Channel ▪ G1S10 - Inter-connector Channel from Yarrawonga to EGM
	Spring	<u>Spring Overbank</u> For ARIs < 40 years, magnitude of	Potential exacerbation of downstream flood impacts	No infrastructure constraints	▪ G1Sp1a - Modified Eildon operation (target release)

Reach	Season	Summary of Current conformance	Constraints/Reasons		Options
			Operational	Infrastructure	
		current floods less than recommended. The current operation of the Goulburn System is not aimed at providing the recommended flood regime. Recommended flows are 15,000 to 60,000 ML/d once per year, depending on Eildon inflows.	resulting from flows in excess of 14,500 ML/d		▪ G1Sp1b - Modified Eildon operation (modify target filling curves to optimise provision of environmental floods) ▪ G1Sp2 - Pump into key wetlands ▪ G1Sp3 - Construct weirs to direct flows into key wetlands
Goulburn River – Goulburn Weir/Nagambie to Murray (Reaches 4 and 5)	Summer	Summer Low 5-36% of days in period meet recommended flows. The recommended minimum summer flow in this reach is 610 ML/d. The BE requirement (250 ML/d) is currently met but there is no current requirement to meet the 610 ML/d recommended minimum flow.	No operational constraints	No infrastructure constraints	▪ No constraints – no options required
	Spring	Spring Overbank Magnitude of current floods is less than recommended for all ARIs in reach 4 and for ARIs > 10 years for reach 5. Recommended flows are 15,000 to 60,000 ML/d once per year, depending on Eildon inflows.	Potential exacerbation of downstream flood impacts.	No infrastructure constraints	▪ G1Sp1a as above ▪ G1Sp1b as above ▪ G1Sp2 as above ▪ G1Sp3 as above ▪ G1Sp4 – Minimise harvesting of floods into Waranga Basin

<table>
<tr><th rowspan="2">Reach</th><th rowspan="2">Season</th><th rowspan="2">Summary of Current conformance</th><th colspan="2">Constraints/Reasons</th><th>Options</th></tr>
<tr><th>Operational</th><th>Infrastructure</th><th></th></tr>
<tr><td rowspan="4">Goulburn contribution to Living Murray</td><td rowspan="2">Summer</td><td><u>Summer Low Jan - Mar</u>
7% of days meet recommended summer low flow. Total recommended flow is 1,350 ML/d for 3 months.</td><td>No operational constraints</td><td>No infrastructure constraints</td><td>▪ No constraints – no options required</td></tr>
<tr><td><u>Summer Fresh Jan - Feb</u>
Met 24% of volume recommendation, 25% of duration and number of events is met 0-24% of days in period. Total recommended flow is 2,350 ML/d for 7 days.</td><td>No operational constraints</td><td>No infrastructure constraints</td><td>▪ No constraints – no options required</td></tr>
<tr><td rowspan="2">Spring</td><td><u>Spring Low Jul-Dec</u>
21% of days in period meet recommended spring low flows. Total recommended flow is 10,250 ML/d as required over 6 month period.</td><td>Potential exacerbation of flood impacts below Eildon, if delivered from Eildon in December</td><td>No infrastructure constraints</td><td>▪ GMSp1 - Release from Eildon, plus flood management measures (December)
▪ GMSp2 - Minimise harvesting of flows into Waranga Basin (Jul-Nov)</td></tr>
<tr><td><u>Spring Fresh Aug-Nov</u>
60% conformance with volume, 0-27% conformance with duration and 8-60% conformance with number of events. Total recommended flow is 20,250 ML/d as required to top up flood flows for 1 to 2 months.</td><td>Potential exacerbation of flood impacts below Eildon</td><td>No infrastructure constraints</td><td>▪ GMSp3 - Release from Eildon plus flood management measures (higher standard than GMsp1)
▪ GMSp2 as above</td></tr>
</table>

Reach	Season	Summary of Current conformance	Constraints/Reasons		Options
			Operational	Infrastructure	
Broken Creek	Irrigation Season	September to April Low Flows 94-95% of flows meet recommended low flows. A minimum flow of 30-40 ML/d is recommended to keep fish ladders open. August to April Low Flows 67-80% of flows meet recommended low flow from August-April. A minimum flow of 80-140 ML/d is recommended to control Azolla accumulation for dissolved oxygen management.	Need to supply peak irrigation demand which fully utilises available channel capacity	Lack of available channel capacity during peak demand periods Lack of control of low flows along Creek	▪ BI1 - Inter-connector from Yarrawonga to Broken Creek (100ML/d) ▪ BI2a - Increased Capacity from Murray Valley – enlarge channels ▪ BI2b - Increased Capacity from Murray Valley – purchase channel capacity ▪ BI3a - Increased Capacity from Shepparton – augment EGM ▪ BI3b - Increased Capacity from Shepparton – purchase EGM channel capacity ▪ BI4 - Additional capacity from Upper Broken Creek Note: All options will also require measures to improve control of low flows along Broken Creek.

Reach	Season	Summary of Current conformance	Constraints/Reasons		Options
			Operational	Infrastructure	
	Spring	<u>August to November Freshes</u> 88% conformance with volume, 17-88% conformance with number of events and 51% conformance with duration. Recommended spring fresh is 500 ML/d for seven days at short notice in response to rapid azolla blooms.	Need to supply peak irrigation demand which fully utilises available channel capacity Long travel times from source to, and along, Creek	Lack of available channel capacity	▪ BSp1 – Inter-connector from Yarrawonga to Broken Creek (500ML/d) ▪ BSp2 - Offline storage near upstream end of Azolla affected reach ▪ BSp3a - Increased Capacity from Murray Valley – enlarge channels ▪ BSp3b - Increased Capacity from Murray Valley – purchase channel capacity ▪ BSp4a - Increased Capacity from Shepparton – augment EGM ▪ BSp4b - Increased Capacity from Shepparton – purchase EGM channel capacity ▪ BSp5 - Additional capacity from Upper Broken Creek

5. Campaspe Systems – Constraints and Options

5.1 Introduction

This Chapter provides an overview of the operational and infrastructure constraints associated with the delivery of the recommended environmental flows in the Campaspe system. Constraints are summarised in Table 17, and discussed further in Section 5.2. This Chapter also lists a range of options for the delivery of each of the recommended environmental flow regime components in each reach. Options are summarised in Table 17, and further details are provided in Appendix I. The general discussion of constraints and options presented in Section 4.1 also applies to this Chapter.

5.2 Constraints

5.2.1 Coliban River

Delivery of low flows to the Coliban River from Malmsbury Reservoir is partially constrained by the existing outlet, which has no capacity to release flows between 10-15 ML/d and 45 Ml/d from the Reservoir to the Coliban Main Channel. The Coliban Main Channel has two outfalls with a total capacity of 130 ML/d to release water to Coliban River.

There are no infrastructure constraints to delivery of the recommended winter bankfull flow from Malmsbury (6,000 ML/d (upstream conformance point) to 12,000 ML/d (downstream conformance point) every 3 years) via the spillway gates. Some modification to current operation would however be required.

A flow of 8,700 ML/d (Graham Hall, NCCMA, pers.comm.) will overtop the Calder Highway at Malmsbury. Depending on the magnitude of inflows between the two conformance points at the time the flow is required, this may be a constraint to the delivery of the winter bankfull flow component.

5.2.2 Campaspe River

The major constraint to the delivery of recommended maximum summer low flows to the Campaspe River downstream of Lake Eppalock is the need to supply peak irrigation demands, via the River, during the irrigation season. This includes private diverter demands, and supplies to the Campaspe Irrigation District. For the reaches upstream of the Campaspe siphon it also includes supplement flows to the Waranga Western Channel in seasons when this is required.

Deliveries of recommended winter bankfull and overbank flows to the Campaspe River downstream of Eppalock, which range from 8,000 to 12,000 ML/d, are constrained by the available outlet capacity of Lake Eppalock. At less than fully supply level, Eppalock outlet capacity is 1,850 ML/d. Downstream of Campaspe siphon, part of the recommended winter bankfull and overbank flow could also be delivered from the Waranga Western Channel. This is constrained by outfall capacity (1,470 to 2,300 ML/d), and off-season maintenance requirements.

The recommended Living Murray winter bankfull flow from the Goulburn and Campaspe systems combined is 20,000 ML/d. Infrastructure capacity would constrain delivery of this entirely from the Campaspe. It would also be constrained by downstream flooding, as evacuation of the Rochester Caravan Park commences at a Campaspe flow of 19,000 ML/d (Graham Hall, NCCMA, pers.comm.). Around 1,470 to 2,300 ML/d could be delivered from the Goulburn supply system via the Waranga Western Channel.

Table 17 Campaspe System Constraints and Options

Reach	Season	Summary of Current conformance	Constraints/Reasons		Options
			Operational	Infrastructure	
Coliban River – Malmsbury Reservoir to Lake Eppalock	Summer	Summer Low Flows 56% conformance with low flows. Recommended low flow is 5 ML/d.	No operational constraints	Current Malmsbury Reservoir outlet works do not enable releases to Coliban Channel of between 10-15 and 45 ML/d (releases of more than 10-15 ML/d likely to be required due to losses)	▪ C1S1 - Modify Malmsbury Reservoir outlet to allow releases between 10-15 ML/d and 45 ML/d
		Summer Freshes 73% conformance with volume, 39% conformance with number and 42% conformance with duration. Recommend flow is 100ML/d and 200 ML/d, one of each per year, for 3 days each.	No operational constraints	Current works limit releases (from Coliban Channel) to River to 130 ML/d through a 300 mm outlet and a scour outlet. Note that the scour outlet is not designed for routine operation.	▪ C1S2 - Increase Coliban Main Channel outfall capacity to Coliban River to 200 ML/d

Reach	Season	Summary of Current conformance	Constraints/Reasons		Options
			Operational	Infrastructure	
	Winter	Winter Low Flows 48% conformance with low flows. A flow of 35 ML/d (or natural) is recommended.	No operational constraints	Current Malmsbury outlet works do not enable releases to Coliban Channel of between 10-15 and 45 ML/d	▪ C1S1 as above
		Winter Freshes 85% conformance with volume, 49% conformance with number and 57% conformance with duration. Recommended flow is 700 ML/d for 3 days, 4 times per year.	No operational constraints	Current works limit releases (from Coliban Channel) to River to 130 ML/d	▪ C1W1 – Construct a pondage downstream of Malmsbury Reservoir ▪ C1W2 - Increase capacity of Malmsbury Reservoir outlet works to 700 ML/d ▪ C1W3 - Modify Malmsbury operation, including additional releases from upstream storages

Reach	Season	Summary of Current conformance	Constraints/Reasons		Options
			Operational	Infrastructure	
		Winter Bankfull Flow Aug-Sep 35% conformance with volume, 35% conformance with number and 100% conformance with duration. A flow of 12,000 ML/d occurring once every 3 years for 1 day is recommended	Calder Highway at Malmsbury overtopped by a flow of 8,700 ML/d, which may be a constraint, depending on magnitude of downstream inflows at time bankfull flow is required	No infrastructure constraints to release of 12,000 ML/d via spillway gates. Note release of only 6,000 ML/d may be required depending on downstream tributary inflows. May also be constrained by volume of Malmsbury reservoir, and magnitude of tributary inflows.	▪ C1W4 - Modify Malmsbury release patterns to produce bankfull flow recommendations
Campaspe River – Lake Eppalock to Campaspe Weir	Summer	Summer Cease to Flow Feb-May 10% conformance with volume, 10% conformance with number and 36% conformance with duration. Cease to flow is recommended once per year for 14 days.	Need to supply irrigation demand and WWC (Campaspe supplement) from Lake Eppalock in summer	No infrastructure constraints	▪ C2S1 - Pipeline or channel from Lake Eppalock to Campaspe Weir ▪ C2S2 - On-farm and regional winter-fill storages ▪ C2S3 - Purchase of CID and all PD entitlements for sale to Bendigo ▪ C2S4 - Supply CID and PDs downstream of Campaspe Siphon from WWC ▪ C2S5 - Offline storage near Campaspe Weir, filled in winter ▪ C2S6 - Use of Green's Lake

Reach	Season	Summary of Current conformance	Constraints/Reasons		Options
			Operational	Infrastructure	
		Summer Low Flows 7% conformance. A flow of 10 ML/d (or natural) is recommended.	Need to supply irrigation demand and WWC (Campaspe supplement) from Lake Eppalock in summer	No infrastructure constraints	▪ C2S1 as above ▪ C2S2 as above ▪ C2S3 as above ▪ C2S4 as above ▪ C2S5 as above ▪ C2S6 as above ▪ C2S7 - Pulse discharges from Lake Eppalock
		Summer Freshes Current flows are substantially higher than recommended freshes of 100 ML/d, 3 times per year for 5 days			
	Winter	Winter Low Flows 41% of days in period conform with recommendation. A flow of 100 ML/d (or natural) is recommended	No operational constraints	No infrastructure constraints	▪ No constraints - no options required
		Winter High Flow 37% conformance with volume, 3% conformance with number and 83% conformance with duration. A flow of 1,000 ML/d occurring 4 times per year (or natural), for 4 days is recommended.	No operational constraints	No infrastructure constraints	▪ No constraints - no options required
		Winter Bankfull Flow Aug-Sep 17% conformance with volume and number, and 100% conformance with duration. A flow of 10,000 ML/d, once per year (or natural) for 2 days is recommended.	No operational constraints	Lack of Lake Eppalock outlet capacity at less than FSL (maximum 1,850 ML/d)	▪ C2W1 - Operate Lake Eppalock differently ▪ C2W2 - Increase capacity of Lake Eppalock outlet works to 12,000 ML/d at lower

Reach	Season	Summary of Current conformance	Constraints/Reasons		Options
			Operational	Infrastructure	
		Winter Overbank Flow Aug 6% conformance with volume and number and 100% conformance with duration. A flow of 12,000 ML/d, once per year for 1 day is recommended.			storage levels ▪ C2W3 - Construct pondage downstream of Lake Eppalock
Campaspe River: Campaspe Weir to Campaspe Siphon	Summer	Summer Low Flows 37% of days in period conform with recommendation. A flow of between 10 ML/d and 20 ML/d is recommended.	Need to supply irrigation demand and WWC (Campaspe supplement) from Lake Eppalock in summer	No infrastructure constraints	▪ C3S1 - Pipeline or channel from Campaspe Weir to Campaspe Siphon ▪ C3S2 - On-farm winter-fill storages ▪ C3S3 - Purchase of all PD entitlements downstream of Campaspe Weir for sale to Bendigo or upstream irrigators ▪ C3S4 – Supply PD demand from adjacent channel system
		Summer Freshes Poor conformance with summer freshes (Nov to Dec flows lower and Feb to May higher than env. Flow req.). A flow of 100 ML/d occurring 3 times a year (or natural) for 6 days is recommended			
	Winter	Winter Low Flows 31% of days in period conform with recommendation. A flow of 200 ML/d (or natural) is recommended.	No operational constraints	No infrastructure constraints	▪ No constraints - no options required
		Winter High Flow 61% conformance with volume, 22% conformance with number and 43% conformance with duration. A flow of 1,500 ML/d occurring 4 times per year (or natural), for 4 days is recommended.	No operational constraints	No infrastructure constraints	▪ No constraints - no options required

Reach	Season	Summary of Current conformance	Constraints/Reasons		Options
			Operational	Infrastructure	
		Winter Bankfull Flow 17% conformance with volume and number and 76% conformance with duration. A flow of 8,000 ML/d twice per year (or natural) for 2 days is recommended Winter Overbank Flow Aug-Sep 19% conformance with volume and number, and 100% conformance with duration. A flow of 12,000 ML/yr, once per year for 1 day is recommended	No operational constraints	Lack of Lake Eppalock outlet capacity at less than FSL (maximum 1,850 ML/d)	▪ C2W1 as above ▪ C2W2 as above ▪ C2W3 as above ▪ C3W1 - Modify Eppalock releases to piggyback on high tributary inflows
Campaspe River: Campaspe Siphon to the River Murray	Summer	Summer Low Flows 21% of days in period conform with recommendation. A flow of between 10 ML/d and 20 ML/d is recommended. Conformance likely to have been significantly better since 2000 due to tightened operation as a result of the drought.	Need to supply irrigation demand in summer of approx 15 ML/d. Note that allowance for losses may require additional flow to be released that then exceeds the recommended flow.	No infrastructure constraints if supplied from the Campaspe system.	▪ C4S1 - Pipeline or channel from Campaspe Siphon to River Murray ▪ C4S2 - On-farm winterfill storages ▪ C4S3 - Purchase of reach PD entitlements for sale to Bendigo or upstream irrigators ▪ C4S4 - Supply PD demand from adjacent channel systems

Reach	Season	Summary of Current conformance	Constraints/Reasons		Options
			Operational	Infrastructure	
		Summer Freshes Feb-May 57% conformance with volume, 6% conformance with number and 38% conformance with duration. A flow of 100 ML/d occurring 3 times per year (or natural) for 6 days is recommended	No operational constraints	No infrastructure constraints	
	Winter	Winter Low Flow 29% of days in period conform with recommendations. A flow of 200 ML/d (or natural) is recommended.	No operational constraints if supplied from the Campaspe system. Channel access constraint in some years due to winter maintenance if supplied from the Waranga Western Channel.	No infrastructure constraints	▪ C4W1 - Modified WWC maintenance program to reduce frequency of maintenance
		Winter High Flow 62% conformance with volume, 50% conformance with number and 42% conformance with duration. A flow of 1,500 ML/d occurring twice per year (or natural), for 4 days is recommended.	No operational constraints if supplied from the Campaspe system. Channel access constraint in some years due to winter maintenance if supplied from the Waranga Western Channel.	No infrastructure constraints	▪ C4W1 as above

Reach	Season	Summary of Current conformance	Constraints/Reasons		Options
			Operational	Infrastructure	
		<u>Winter Bankfull Flow Aug-Sep</u> 17% conformance with volume and number and 31% conformance with duration. A flow of 9,000 ML/d twice per year (or natural) for 2 days is recommended.	Winter maintenance of Waranga Western Channel	Lack of Lake Eppalock outlet capacity at less than FSL (maximum 1,850 ML/d), and WWC outlet capacity (2,300 ML/d) Outfall capacity of Waranga Western Channel (1,470 to 2,300 ML/d)	▪ C2W1 as above ▪ C2W2 as above ▪ C2W3 as above ▪ C3W1 as above ▪ C4W1 as above
Living Murray Contribution	Winter	<u>Winter High Flow Jul-Dec</u> 54% conformance with volume, less than 55% conformance with number of events, and duration conformance ranging from 10-100%. A total flow of 2,200 ML/d is recommended, as required to provide flows to Gunbower Forest.	Winter maintenance of Waranga Western Channel	Lack of Lake Eppalock outlet capacity at less than FSL (maximum 1,850 ML/d) Outfall capacity of Waranga Western Channel (1,470 to 2,300 ML/d)	▪ M1W1 - Increase outlet capacity of Eppalock to 2,200 ML/d at lower storage levels ▪ C4W1 as above

Reach	Season	Summary of Current conformance	Constraints/Reasons		Options
			Operational	Infrastructure	
		Winter Overbank Flow Aug-Nov A flow of 20,200 ML/d combined from the Goulburn and Campaspe, for 1 to 2 months, is recommended as often as required to top up flood flows. It is assumed that a flow of around 2,000 ML/d would be provided from the Campaspe system. The level of conformance was not assessed but is assumed similar to winter high flow.	Winter maintenance of Waranga Western Channel	Lack of Lake Eppalock outlet capacity at less than FSL (maximum 1,850 ML/d) Outfall capacity of Waranga Western Channel (1,470 to 2,300 ML/d)	▪ M1W1 as above ▪ C4W1 as above

6. Birches and Tullaroop Creek Systems – Constraints and Options

6.1 Introduction

This Chapter provides an overview of the operational and infrastructure constraints associated with the delivery of the recommended environmental flows in the Birches and Tullaroop Creek system, upstream of Tullaroop Reservoir. Constraints are summarised in Table 18 and discussed further in Section 6.2. This Chapter also lists a range of options for the delivery of each of the recommended environmental flow regime components in each reach. Options are summarised in, and further details are provided in Appendix J. The general discussion of constraints and options presented in Section 4.1 also applies to this Chapter.

6.2 Constraints

The delivery of virtually all recommended flow components to Birches and Tullaroop Creeks is constrained by the available outlet capacity of Newlyn Reservoir and Hepburn Lagoon. At low levels, these are estimated to be 5 ML/d and 1 ML/d respectively.

There is little available information on potential flood constraints to the delivery of winter bankfull flows to these streams (Graham Hall, NCCMA, pers.comm.). The bankfull flow capacity of Tullaroop Creek downstream of the Creswick Creek confluence is estimated to be around 5,500 ML/d (Graham Hall, NCCMA, pers.comm.), which suggest that delivery of the recommended winter bankfull flow of 2,580 ML/d to this reach is unlikely to be constrained by flooding.

Table 18 Birches and Tullaroop Creek Constraints and Options

Reach	Season	Summary of Current conformance	Constraints/Reasons		Options
			Operational	Infrastructure	
Reach Birches Creek: Newlyn Reservoir to confluence with Hepburn Race	Summer	Summer Low Flow 65% conformance with low flows. A flow of 3 ML/d (or natural), occurring once per year, for 6 months is recommended.	No operational constraints	No infrastructure constraints	▪ No constraints – no options required
		Summer Freshes Fresh flows – 75% conformance with volume, 32% conformance with number of events and 35% duration. Flow of 10 ML/d, occurring four times per year (or natural), for 3 days is recommended.	No operational constraints	Lack of Newlyn Reservoir outlet capacity (typically 5 ML/d at low storage levels)	▪ B1S1 - Decommission Newlyn Reservoir ▪ B1S2 - Increase Newlyn Reservoir outlet capacity at low storage levels to 10 ML/d
	Winter	Winter low flow Met 62% of time. A flow of 10 ML/d, once per year, for 6 months is recommended	No operational constraints	Lack of Newlyn Reservoir outlet capacity (typically 5 ML/d at low storage levels)	▪ B1S1 as above ▪ B1S2 as above
		Winter Fresh flow Met 85% of volume requirement and 33% of number of events and 65% duration. A flow of 40 ML/d, 3 times per year (or natural) for 5 days is recommended.	No operational constraints	Lack of Newlyn Reservoir outlet capacity (typically 5 ML/d at low storage levels)	▪ B1S1 as above ▪ B1W1 - Increase Newlyn Reservoir outlet capacity at low storage levels to 40 ML/d
		Winter high flow Met 70% of volume requirement and 50% of number of events and 50% duration. Flow of 160 ML/d, three times per year for 5 days is recommended.	No operational constraints	Lack of Newlyn Reservoir outlet capacity (typically 5 ML/d at low storage levels)	▪ B1S1 as above ▪ B1W2 - Increase Newlyn Reservoir outlet capacity at low storage levels to 160 ML/d

Birches Creek: Hepburn Race to Tullaroop Reservoir Tullaroop Creek: Creswick Creek confluence to Tullaroop Reservoir (Reaches 2,3 and 4)	Summer	<u>Summer Low Flows</u> 36-58% of days in period conform with low flow recommendation. Flow of 5-10 ML/d (or natural), once per year for 6 months is recommended	No operational constraints	Lack of storage outlet capacity (typically 5 ML/d at low levels for Newlyn Reservoir, and 1 ML/d at low levels for Hepburn Lagoon)	▪ B1S1 as above ▪ B2S1- Decommission Hepburn Lagoon ▪ B2S2 - Increase Hepburn Lagoon outlet capacity at low levels to 10 ML/d ▪ B1S2 as above
		<u>Summer Fresh Flows</u> 55-80% conformance with volume, 6-27% conformance with number of events and 30-50% with duration. Flow of 15-27 ML/d, 4 times per year (or natural) for 3 - 7 days is recommended.	No operational constraints	Lack of storage outlet capacity (typically 5 ML/d at low levels for Newlyn Reservoir, and 1 ML/d at low levels for Hepburn Lagoon)	▪ B2S1 as above ▪ B1S1 as above ▪ B2S3 - Increase Hepburn Lagoon outlet capacity at low storage levels to 27 ML/d ▪ B2S4 - Increase Newlyn Reservoir outlet capacity at low storage levels to 27 ML/d
	Winter	<u>Winter low flow</u> Met 66-86% of time. A flow of 10-20 ML/d (or natural) once per year for 6 months is recommended.	No operational constraints	Lack of storage outlet capacity (typically 5 ML/d at low levels for Newlyn Reservoir, and 1 ML/d at low levels for Hepburn Lagoon)	▪ B2S1 as above ▪ B1S1 as above ▪ B2S3 as above ▪ B2S4 as above

		Winter Fresh flow Met 85-90% of volume requirement and 26-55% of number of events and 60-70% duration. Flow of 55 – 250 ML/d, 3 times per year (or natural) for 5 days is required.	No operational constraints	Lack of storage outlet capacity (typically 5 ML/d at low levels for Newlyn Reservoir, and 1 ML/d at low levels for Hepburn Lagoon)	▪ B2S1 as above ▪ B1S1 as above ▪ B2W1- Increase outlet capacity at Hepburn Lagoon at low storage levels to 275 ML/d ▪ B2W2 – Increase outlet capacity at Newlyn Reservoir at low storage levels to 275 ML/d
		Winter high flow Met 70-75% of volume requirement and 45-76% of number of events and 65-75% duration (for reaches 2 and 3 only). Flow of 275 ML/d, twice per year, for 3 days is recommended from Hepburn Lagoon. Downstream flow of 200 ML/d, three times per year for 3 days is recommended.	No operational constraints	Lack of storage outlet capacity (typically 5 ML/d at low levels for Newlyn Reservoir, and 1 ML/d at low levels for Hepburn Lagoon)	▪ B1S1 as above ▪ B2S1 as above ▪ B2W1 as above ▪ B2W2 as above
		Bankfull flow Met 35-40% of volume requirement and 63-69% of number of events and 100% duration (for reaches 3 and 4 only). Flow of 1,300 ML/d, once per year for 1 day is recommended for reach 3. Downstream flow in Tullaroop Ck of 2,580 Ml/d, once per year for 1 day is recommended.	No operational constraints	Lack of storage outlet capacity (typically 5 ML/d at low levels for Newlyn Reservoir, and 1 ML/d at low levels for Hepburn Lagoon)	▪ B2S1 as above ▪ B1S1 as above ▪ B2W3 - Increase Hepburn Lagoon outlet capacity to 1,300 ML/d ▪ B2W4 - Increase Newlyn Reservoir outlet capacity to 1,300 ML/d

7. Loddon Systems – Constraints and Options

7.1 Introduction

This Chapter provides an overview of the operational and infrastructure constraints associated with the delivery of the recommended environmental flows to the Loddon River, and to Tullaroop Creek downstream of Tullaroop Reservoir. Constraints are summarised in Table 19, and discussed further in Section 7.2. This Chapter also lists a range of options for the delivery of each of the recommended environmental flow regime components in each reach. Options are summarised in Table 19, and further details are provided in Appendix K. The general discussion of constraints and options presented in Section 4.1 also applies to this Chapter.

7.2 Constraints

The major constraint to the delivery of recommended summer flow regimes in all reaches, with the exception of the reach of the Loddon River between Loddon Weir and Kerang Weir, is the need to supply peak irrigation demands and flow supplements, via the River, during the irrigation season. The recommended summer low flow regime between Cairn Curran and Loddon Weir, and on Tullaroop Creek, is a minimum flow of between 10 and 20 ML/d. Current summer irrigation flows are much larger than this, and the current regime therefore technically conforms to the recommendations for this flow component. However a summer fresh regime is also recommended for these reaches, as is a summer cease to flow regime for the reach between Cairn Curran and Laanecoorie. This implies that, despite the strict wording of the recommendations, the preferred regime should actually consist of periods of low or no flow, interspersed by occasional higher fresh flows. The current regimes do not conform to these requirements in any of these reaches.

Delivery of recommended anytime high flow recommendation of 3,000 ML/d once in two years to Tullaroop Creek downstream of Tullaroop Reservoir is constrained by the available outlet capacity of the Reservoir. At less than fully supply level, Tullaroop outlet capacity is currently restricted to 450 ML/d due to vibration of the outlet works (although actual releases of 730 to 740 ML/d have been achieved). Bankfull flow capacity of Tullaroop Creek downstream of Tullaroop Reservoir is estimated to be around 5,000 ML/d (Graham Hall, NCCMA, pers.comm.), which suggest that delivery of the recommended anytime high flow of 3,000 ML/d to this reach is unlikely to be constrained by flooding.

Delivery of the recommended winter overbank and anytime high flows of 3,000 ML/d every year to the Loddon down stream of Cairn Curran is constrained by the available outlet capacity of the Reservoir. At less than spillway sill level, Cairn Curran outlet capacity is only around 1,600 ML/d. In this reach, overtopping of roads would not start to occur until flows reached around 21,000 ML/d (Graham Hall, NCCMA, pers.comm.). This is therefore most unlikely to constrain delivery of recommended winter high and overbank, and anytime high flows of 3,000 ML/d.

Between Laanecoorie and Serpentine Weir, significant flooding would only start to occur at flows of around 28,000 ML/d (Graham Hall, NCCMA, pers.comm.). Flows of this order would discharge overland towards Judyong and Long Plains Creek from around 2 km upstream of Serpentine Weir. This would not constrain delivery of any of the recommended flows to this reach.

In the reach downstream of Serpentine Weir, flow in excess of 10,000 ML/d would break out from the main River towards Butchers Lagoon (Graham Hall, NCCMA, pers.comm.). Whilst this is less than the recommended winter overbank flow of 13,000 ML/d, the small difference between the flows would justify further investigations to confirm that this is not a constraint to delivery of the recommended flow regime.

Delivery of the recommended flow regime to the Loddon downstream of Serpentine Weir is constrained by the capacity of the Weir to regulate low flows.

Delivery of the recommended summer low flow regime downstream of Loddon Weir is constrained by the capacity of the Weir to regulate low flows. Goulburn-Murray Water is currently undertaking modifications to the Weir to overcome this. Delivery of recommended summer low flows in this reach would also be constrained by a lack of control over sporadic diversions. This is particularly significant given the length of the reach and associated high summer losses. Flows in excess of around 5,000 ML/d in this reach would breakout towards Kelshes Lagoon (Graham Hall, NCCMA, pers.comm.). Flows of this magnitude are well in excess of any of the recommended flow components in this reach, and would not therefore constrain delivery of the recommended flow regime.

The reach of the Loddon downstream of Loddon Weir also contains the feature known as "The Chute". This is understood to be a block bank with a low flow pipe (2 to 3 ft in diameter – Kathryn Stanislawski, NCCMA, pers.comm.), which serves to direct flow from the Loddon into Wandella and 12 Mile Creeks (Graham Hall, NCCMA, pers.comm.). Further investigations would be required to determine the flow at which breakouts to Wandella and 12 Mile Creeks occur, and the flow split between the Loddon River, Wandella Creek and 12 Mile Creek at this point. Losses in Wandella and 12 Mile Creeks are significant and this would potentially impact on the magnitude of releases from Loddon Weir required to meet the recommended Living Murray winter high flow of 560 ML/d.

The channel capacity of the Loddon River downstream of The Chute is thought to be around 300 ML/d, with excess flows spreading on to the leveed floodplain adjacent to the river (Graham Hall, NCCMA, pers.comm.).

Delivery of the recommended flow regime to the Loddon downstream of Kerang Weir is constrained by the capacity of the Weir to regulate low flows. Flows in excess of around 4,000 ML/d in this reach would start to flood farms (Graham Hall, NCCMA, pers.comm.). Flows of this magnitude are well in excess of any of the recommended flow components in this reach, and would not therefore constrain delivery of the recommended regime.

Table 19 Loddon System Constraints and Options

Reach	Season	Summary of Current conformance	Constraints/Reasons		Options
			Operational	Infrastructure	
Tullaroop Creek: Tullaroop Reservoir to Laanecoorie Reservoir	Summer	Summer Low Flows 100% of days in period comply with recommendations. A minimum of 10 ML/d (or natural) all year, is recommended. Summer Fresh Flows Nov-Apr Met 100% volume, 96% duration and 0% number. Minimum flow of 13.5 ML/d, four times per year for 7 days is recommended.	Need to supply downstream irrigation demand from Tullaroop in summer	No infrastructure constraints	▪ T1S1 - Decommission Tullaroop Reservoir ▪ T1S2 - Pipeline or Channel from Tullaroop to Laanecoorie ▪ T1S3 - Winterfill storage at Fernihurst and on-farm storages for reach PDs ▪ T1S4 - On-farm and regional winter-fill storages ▪ T1S5 - Pipeline from Tullaroop to Cairn Curran Reservoir ▪ T1S6 - Augment capacity of WWC to supply Boort irrigators currently supplied from Tullaroop ▪ T1S7 - Enlarge capacity of Laanecoorie for winterfill from Tullaroop
	Winter	Winter low flow All year 100% of days in period comply with recommendations. A minimum of 10 ML/d (or natural) all year, is recommended.	No operational constraints	No infrastructure constraints	▪ Full conformance - no options required

Reach	Season	Summary of Current conformance	Constraints/Reasons		Options
			Operational	Infrastructure	
		Winter Fresh flow May-Aug Met 28% of volume requirement and 0% of number of events, 57% duration. Minimum flow of 132 ML/d, twice per year for 7 days.	No operational constraints	Vibration of the outlet works is an issue at flows > 450 ML/d	▪ T1W1 - Eliminate Tullaroop outlet vibration
		Winter high flow May-Aug Met 16% of volume requirement and 5% of number of events, 80% duration. A flow of 500 ML/d, twice per year for 4 years in 5, lasting for 4 days is recommended.	No operational constraints	Vibration of the outlet works is an issue at flows > 450 ML/d	▪ T1W1 as above
	Anytime	Anytime High a 100% conformance in volume and number with 43% conformance with duration. Flow of 500ML/d, once per year for 4 years out of 5, for 4 days	No operational constraints	No infrastructure constraints	▪ T1W1 as above
		Anytime High b Met 64% volume requirement and number with 100% conformance with duration. Flow of 3,000 ML/d, once every two years for 1 day is recommended.	No operational constraints	Lack of Tullaroop Reservoir outlet capacity (typically 450 to 740 ML/d)	▪ T1A1 - Increase Tullaroop outlet capacity to 3,000 ML/d ▪ T1A2 - Modify Tullaroop releases to piggyback on high tributary inflows ▪ T1A3 - Construct pondage downstream of Tullaroop ▪ T1S1 as above

Reach	Season	Summary of Current conformance	Constraints/Reasons		Options
			Operational	Infrastructure	
Loddon River – Cairn Curran Reservoir to Laanecoorie Reservoir	Summer	Cease to flow No conformance with cease-to-flow recommendations. Cease-to-flow is recommended once every four years for 2 months.	Need to supply downstream demand from Cairn Curran in summer	No infrastructure constraints	▪ L1S1- Pipeline or channel from Cairn Curran to Laanecoorie including reach PDs ▪ L1S2 - Supply from Tullaroop to Laanecoorie and provide on-farm storages to reach PDs ▪ L1S3 - Pipeline from Cairn Curran to Tullaroop and provide on-farm storages to reach PDs ▪ L1S4 - Augment capacity of WWC to supply Boort irrigators currently supplied from Cairn Curran ▪ L1S5 - Enlarge capacity of Laanecoorie for winterfill from Cairn Curran ▪ L1S6 – Winterfill Storage near Loddon Weir at Fernihurst to cover cease to flow period and provide on-farm storages to reach PDs ▪ L1S7 - On-farm and regional winter-fill storages to cover cease to flow period

Reach	Season	Summary of Current conformance	Constraints/Reasons		Options
			Operational	Infrastructure	
		Summer Low Flows Nov-April 95% of days in period conform with recommendations. Minimum flow of 20 ML/.d is recommended. Summer Freshes Nov-April 100% conformance with volume, 8% conformance with number and 97% conformance with duration. A flow of >35 ML/d, 3 times per year for 7 days is recommended	Need to supply downstream demand from Cairn Curran in summer	No infrastructure constraints	▪ L1S1 as above ▪ L1S3 as above ▪ L1S4 as above ▪ L1S8 - New winter-fill storage near Loddon Weir at Fernihurst to cater for irrigation supplies from Cairn Curran ▪ L1S9 - On-farm and regional winter-fill storages to cater for irrigation supplies from Cairn Curran
	Winter	Winter low flow May-Oct 38% of days in period comply with recommendation. A minimum flow of 35 ML/d is recommended	No operational constraints	No infrastructure constraints	▪ No constraints - no options required
		Winter Freshes May - Aug 48% conformance with volume, 0% conformance with number and 42% conformance with duration. A minimum flow of 181 ML/d, 3 times per year for 25 days is required.	No operational constraints	No infrastructure constraints	▪ No constraints - no options required

Reach	Season	Summary of Current conformance	Constraints/Reasons		Options
			Operational	Infrastructure	
		Winter high flow Aug-Nov 100% conformance with volume and number, and 40% conformance with duration. A flow of 3,000 ML/d, once every 4 years for 4 days is recommended.	No operational constraints	No infrastructure constraints	▪ No constraints - no options required
		Overbank flow June-August 24% conformance with volume and number and 38% conformance with duration. A minimum flow of 3,000 ML/d is recommended once per year for 4 days.	No operational constraints	Lack of Cairn Curran outlet capacity at less than spillway crest level	▪ L1W1 - Increase Cairn Curran outlet works capacity to 3,000 ML/d ▪ L1W2 - Construct pondage downstream of Cairn Curran
	Anytime	High Flow 52% conformance with volume and number, and 30% conformance with duration. A flow of 3,000 ML/d occurring once per year for 4 days is recommended.	No operational constraints	Lack of Cairn Curran outlet capacity at less than spillway crest level	▪ L1W1 as above ▪ L1W2 as above

Reach	Season	Summary of Current conformance	Constraints/Reasons		Options
			Operational	Infrastructure	
Loddon River: Laanecoorie Reservoir to Loddon Weir	Summer	Summer low flow Laanecoorie to Serpentine Weir – recommended low flow of around 15 ML/d is exceeded 99% of days from November to July. Serpentine Weir to Loddon Weir – recommended low flow of around 19 ML/d is exceeded 84% of days from November to April. Summer Freshes Nov-Apr Laanecoorie to Serpentine Weir - 100% conformance with volume, 4% conformance with number and 90% conformance with duration. A minimum flow of 52 ML/d occurring 3 times per year for 13 days is recommended. Serpentine Weir to Loddon Weir - 96% conformance for volume, 44% conformance for number and 63% conformance for duration. Minimal flow of 61 ML/d occurring 3 times per year for 11 days is recommended.	Need to supply downstream demand from Laanecoorie in summer Lack of summer variability	Limited capacity of Serpentine and Bridgewater Weir to regulate low flows	▪ L2S1 - Pipeline or channel from Laanecoorie to Loddon weir ▪ L2S2 - Winterfill storage near Loddon Weir at Fernihurst and on-farm storages for all PDs ▪ L2S3 - On-farm and regional winterfill storages ▪ L2S4 - Augment capacity of WWC to supply Boort irrigators Note: All options will also require increased regulatory capacity of Serpentine and Bridgewater weir (see also Option L2W1 below)

Reach	Season	Summary of Current conformance	Constraints/Reasons		Options
			Operational	Infrastructure	
	Winter	Winter low flow Laanecoorie to Serpentine Weir - 89% of days in period exceed the recommended minimum flow of 52 ML/d from Aug-Oct Serpentine Weir to Loddon Weir - 61% of days exceed the recommended minimum flow of 61 ML/d from May-Oct	No operational constraints	Limited capacity of Serpentine Weir to regulate low flows	▪ L2W1 – Increase regulatory capacity of Serpentine and Bridgewater Weirs
		Winter freshes Aug-Oct Laanecoorie to Serpentine Weir - 88% conformance for volume, 56% conformance for number and 30% conformance with duration. A minimum flow of 900 ML/d occurring twice per year for 9 days is recommended. Serpentine Weir to Loddon Weir - 92% conformance for volume, 64% conformance for number, 50% conformance for duration. Minimum flow of 400 ML/d occurring twice per year for 7 days is recommended	No operational constraints	No infrastructure constraints	▪ No constraints - no options required

Reach	Season	Summary of Current conformance	Constraints/Reasons		Options
			Operational	Infrastructure	
		Winter high flow Laanecoorie to Serpentine Weir - 100% conformance with recommended winter high flow. Flow of 7,300 ML/d occurring one in every 2 years for 1 day is recommended from June-Oct. Serpentine Weir to Loddon Weir - 72% conformance for volume, 44% conformance for number, 49% conformance for duration. Flow >2000 ML/d occurring twice per year for 6 days is recommended from Aug - Oct	No operational constraints	No infrastructure constraints	▪ No constraints - no options required
		Overbank Flow June-Oct Minimal flow of 13,000 ML/d, occurring once every 3 years for 2 days is recommended. *Scientific Panel asserts that overbank flow recommendation is currently achieved 9 years in 27, 2 days duration. Scientific Panel used gauged record at 407229 (Loddon River at Serpentine Weir) for conformance calculations. We have used modelled REALM data for a downstream location (Loddon River Environmental Flows Scientific Panel, 2002).	No operational constraints (Flows of 10,000 ML/d result in breakout flows towards Butchers Lagoon.)	No infrastructure constraints	▪ No constraints - no options required

Reach	Season	Summary of Current conformance	Constraints/Reasons		Options
			Operational	Infrastructure	
Loddon Weir to Kerang Weir	Summer	Summer Cease to flow To be determined - is a potential risk			▪ No flow recommendation at this time – no options specified
		Summer low flow Nov-Apr 87% of days in period comply with recommendation. Flow between 7 and 12 ML/d is recommended	Control of sporadic diversions – long reach with high summer losses	Limited capacity of Loddon Weir to regulate low flows	▪ L3S1 - Flume gates on Loddon Weir to control low flows ▪ L3S2 - Improved management of sporadic diversions to ensure low flow requirements are maintained ▪ L3S3 - Repair Twelve Mile Creek regulator
		Summer Freshes Jan-Feb 8% conformance for volume and number and no conformance for duration. Minimum flow of 50 ML/d occurring once per year for 14 days is recommended	No operational constraints	No infrastructure constraints (however refer discussion of "The Chute' in Section 7.2) Channel capacity constraints in some years if supplied from the Waranga Western Channel	
	Winter	Winter low flow May-Oct 37% of days in period comply with recommendation. Minimum flow of 61 ML/d is recommended	No operational constraints if supplied from the Loddon system. Channel access constraint in some years due to winter maintenance if supplied from the Waranga Western Channel	No infrastructure constraints (however refer discussion of "The Chute' in Section 7.2)	▪ L3W1 - Supply from WWC

Reach	Season	Summary of Current conformance	Constraints/Reasons		Options
			Operational	Infrastructure	
		Overbank Flow Jul-Oct 44% conformance for volume and number and 47% conformance for duration. A minimum flow of 400 ML/d occurring twice per year for 7 days is recommended.	No operational constraints if supplied from the Loddon system. Channel access constraint in some years due to winter maintenance if supplied from the Waranga Western Channel	No infrastructure constraints (however refer discussion of "The Chute' in Section 7.2)	▪ L3W1 as above
Kerang Weir to River Murray	Summer	Summer Cease to flow To be determined - is a potential risk			▪ No flow recommendation at this time – no options specified
		Summer low flow Nov-Apr 3% of days in period comply with recommendation. Flow between 7 and 12 ML/d is recommended	Need to supply downstream demand from Kerang Weir in summer	Limited capacity of Kerang Weir to regulate low flows	▪ L4S1 - Pipeline or channel from Kerang Weir to River Murray, plus Kerang Weir modifications to enable delivery of 7 to 12 ML/d ▪ L4S2 - On-farm storages, plus Kerang Weir modifications to enable delivery of 7 to 12 ML/d
		Summer Freshes Jan-Feb 92% conformance for volume and number and 45% conformance for duration. Minimum flow of 50 ML/d occurring once per year for 14 days is recommended	Need to supply downstream demand from Kerang Weir in summer Lack of variability	No infrastructure constraints	▪ L4S1 as above ▪ L4S2 as above

Reach	Season	Summary of Current conformance	Constraints/Reasons		Options
			Operational	Infrastructure	
	Winter	Winter low flow May-Oct 99% of days in period comply with recommendation. Minimum flow of 61 ML/d is recommended	No operational constraints	No infrastructure constraints	▪ No constraints - no options required
		Winter high flow Jul-Oct 100% conformance for volume, 64% conformance for number and 75% conformance for duration. A minimum flow of 400 ML/d occurring twice per year for 7 days is required.	No operational constraints	No infrastructure constraints	▪ No constraints - no options required
		Overbank Flow 100% conformance for volume, 68% conformance for number and 72% conformance for duration. A minimum flow of 1,200 ML/d is recommended occurring twice per year for 7 days.	No operational constraints	No infrastructure constraints	▪ No constraints - no options required
Living Murray contribution	Summer	High flow Nov-Apr 96% conformance with volume, 24-92% with number of events and 4-13% with duration. A total flow of 510 ML/d for 1 to 2 months as often as required is recommended.	No operational constraints (Note potentially high but poorly understood losses below Loddon Weir that could require additional flows to be released above the recommended 510 ML/d).	No infrastructure constraints if supplied from the Loddon (however refer discussion on The Chute in Section 7.2). Channel capacity constraints in some years if supplied from the Waranga Western Channel	No constraints no options required

Reach	Season	Summary of Current conformance	Constraints/Reasons		Options
			Operational	Infrastructure	
	Winter	Winter high flow May-Oct 100% conformance with volume, 68-100% with number of events and 14-23% with duration. A total flow of 561 ML/d for 1 to 2 months as often as required is recommended.	No operational constraints if supplied from the Loddon (Note potentially high but poorly understood losses below Loddon Weir that could require additional flows to be released above the recommended 561 ML/d). Channel access constraint in some years due to winter maintenance if supplied from the Waranga Western Channel	No infrastructure constraints if supplied from the Loddon (however refer discussion on The Chute in Section 7.2).	▪ L3W1 as above

8. Methodology for Development Option Packages

8.1 Overview

The previous section has canvassed the conceptual development of options to deliver specific flow components in reaches. In order to deliver the full suite of environmental flow recommendations it will be necessary to package options. This chapter outlines the basis on which options can be packaged and is presented as an overview. The proposed methodology has been applied to the Goulburn System as a case study in Chapter 9.7. Importantly, this project only examines options to address physical and operational constraints for the delivery of environmental flows. As outlined in Chapter 1 the delivery of environmental flows is also dependent on the availability of water for release. In light of this it is not possible to prioritise or package options until this arm of the assessment has been undertaken.

8.2 Key concepts

The primary objective of option packaging is to identify a suite of options that will deliver the maximum benefit in terms of fulfilling the environmental flow recommendations. To this end, options will be packaged on the basis of their performance against two factors:

- **Effectiveness -** Options will be packaged in order to deliver the best possible environmental flow outcomes.
- **Efficiency -** Options will be packaged in order to deliver environmental flows in the most cost-effective manner.

Each of these factors is discussed below. Importantly, assessing the effectiveness of a package of options is a not simply a matter of evaluating the number of flow components delivered by a single option. It is critical that the packaging is able to group options that complement each other and are able to deliver the full suite of environmental flow requirements.

8.3 Package Units

Packages will be developed for each *discrete system*. This is defined as the smallest length of river beyond which options for selection will have limited influence. For example, in the Campaspe System, the Coliban River is considered as a discrete system because options for the delivery of environmental flows in this reach would have virtually no influence downstream of Lake Eppalock. In contrast, the reaches downstream of Lake Eppalock are grouped together because options that deliver environmental flows in the reach between Lake Eppalock and Campaspe Weir have the potential to influence the delivery of environmental flow requirements in downstream reaches. On this basis the following discrete systems have been identified:

- Broken Creek;
- Goulburn River;
- Coliban River;
- Campaspe River between Lake Eppalock and the confluence with the River Murray;
- Birches Creek, and Tullaroop Creek upstream of Tullaroop Reservoir; and
- Tullaroop Creek downstream of Tullaroop Reservoir, and the Loddon River from Cairn Curran Reservoir to the confluence of the Loddon River with the River Murray.

Option packages will be developed for each of these systems. In some (exceptional) cases, options will have an impact beyond their units and where this occurs it is accompanied by a comment.

8.4 Effectiveness of options

As outlined above, the primary objective of options is to deliver environmental benefit through the delivery of environmental flows. This means that the effectiveness of an option can be best expressed as the extent to which it achieves this primary objective. In light of this, the effectiveness of an option can also be expressed as the 'environmental benefit index'. Option effectiveness is a function of:

- the number of components of the desired environmental flow regime that are delivered; and
- the relative value or importance of fulfilling each flow component to the ultimate delivery of an instream environmental benefit.

1) That is:

$$\textbf{Effectiveness (Option}_{ik}\textbf{)} = \sum(\mathbf{w}_j.\mathbf{p}_{i\text{-}jk})/\mathbf{n}, \text{ where}$$

- $\mathbf{w}_{jk}$ is the weight assigned to each flow component *j* within the defined environmental flow regime for a single river reach *k* (such that $\sum w_j = 5.0$, if the reach has five flow components), and
- $\mathbf{p}_{i\text{-}jk}$ is the performance of Option *i* with respect to the particular flow component *j* in that reach *k*.
- **n** is the number of possible flow components within the system.

The performance rating $p_{i\text{-}j}$ for a specific option has been assigned as follows:

The option completely inhibits delivery of the flow component	The option partially inhibits the delivery of the flow component	The option has no effect on delivery of the flow component.	The option partially delivers the flow component.	The option fully delivers the flow component.
-2	-1	0	+1	+2

At this stage, is proposed that each flow component is weighted equally in the absence of more detailed information on the relative merit of flow components in each reach. This weighting may be re-visited in light of more detailed information on the relative benefit achieved through the fulfilment of different flow components.

It is important to recognise that weighting flow components equally is not neutral; it can mean that the effectiveness may be biased towards specific seasons because of unequal flow recommendations across summer and winter. For example, in the Coliban River there are two recommendations for summer flows and three recommendations for winter flows. This means that an equal weighting of flow components will mean that the effectiveness of options will be skewed towards the delivery of winter flows. Importantly, this is a function of the flow recommendations rather than the packaging process. This could be corrected by weighting summer flows higher than winter flows. Equally, if there is one flow component which delivers considerably more environmental benefit than another flow component then it could be assigned a relatively higher weighting.

Environmental flows recommendations vary by reach and by season and whilst the effectiveness can be expressed as a single ‘environmental benefit index’ this does not capture the full complexity of time and space variability. Capturing these dimensions is particularly important when packaging options as it is desirable to package options which are complementary. For example, two options may be highly effective in delivering the same flow components. In this situation there is no benefit gained from implementing both options. In contrast, two options may be highly effective in delivering complementary flow components. In this situation there is considerable benefit from packaging these options.

In order to address the issue of space and time variability in an explicit way, options have been assigned a performance rating against each of the flow components within the relevant system. Options can then be visually combined into ‘packages’ to deliver the desired flow components across multiple reaches to provide instream environmental benefits for an entire river system. The figure below provides an example. It can be seen that, there would be no advantage in combining Option One with Option Two as they both address the same flow components. Conversely packaging either of these with Option Three would delivery the full range of flow components.

SKM

	OPTION	DESCRIPTION	Reach One		Reach Two	Reach Three	
			SL	SpO	SpO	SpL	SpF
		Weight (%)	100	100	100	100	100
		Option One	2	0	2	2	0
✓		Option Two	2	0	2	2	0
✓		Option Three	0	2	0	0	2
	Selected Package		**2**	**2**	**2**	**2**	**2**

Where possible, options should generally be packaged in order to facilitate the full delivery of all environmental flow recommendations. In some cases this could mean that more than one package of options is possible. In other cases, it may not be possible to achieve full compliance.

8.5 Efficiency of options

Whilst the primary objective of options is to deliver environmental flows, in some cases multiple options will deliver similar flow components. This means that it is necessary to distinguish between options on the basis of additional criteria. The 'efficiency' of options reflects how cost effective options are. Efficiency is defined exclusively in terms of the ratio of effectiveness to capital costs. The Capital Cost (in $ million) has been estimated for each option.

Capital cost estimates are indicative only, based on readily available information, with significant (50%) contingency allowances added to reflect the uncertainty in the estimates. All costs provided are capital costs only and do not include whole life cycle costs or Net Present Value costs. The purpose of these estimates is to assist in ranking of options and they should not be used for any other purpose. Options that are worthy of further consideration will require further investigation that will allow more detailed cost estimates to be developed.

Once capital cost has been determined, the efficiency of the option is determined as follows:

Efficiency = Effectiveness / Capital Cost

Hence a package having an Effectiveness score of 3.5 and costing $0.5 million to implement would have an Efficiency score of (3.5/0.5) = 7. The efficiency of each option is set out in Chapter 9.7. Importantly, the efficiency of an option package will not simply be a matter of summing the efficiency of individual options, as multiple options within packages may deliver the same flow component.

Where options deliver similar flow components, the most efficient option would generally be selected in preference to less efficient options. For example, in the system below both option C2S1

SKM

(Channel or Pipeline from Eppalock to Campaspe Weir) and C2S2 (Regional or on-farm winterfill storages for all reaches) have the same effectiveness rating and achieve conformance for the same flow components. However option C2S1 has a lower cost and hence a higher efficiency rating and would therefore be packaged in preference to option C2S2.

All Options		Eppalock to Campaspe Weir					Campaspe Weir to Siphon				Siphon to Murray			Living Murray		EFFECTIVENESS	$ million	EFFICIENCY
		SCTF	SL	SF	WB	WO	SL	SF	WB	WO	SL	SF	WB	WH	WB			
C2S1	Channel or Pipeline from Eppalock to Campaspe Weir	2	2	2	0	0	0	0	0	0	0	0	0	0	0	0.21	$ 100.00	0.002
C2S2	Regional or onfarm winterfill storages for all reaches	2	2	2	0	0	0	0	0	0	0	0	0	0	0	0.21	$ 350.00	0.001

Significantly, this packaging may be revised in light of the assessment outlined in Chapter 1.1 if it is demonstrated that option C2S1 is not feasible, robust or has adverse secondary impacts.

9. Option Assessment

9.1 Overview

An assessment framework has been developed to enable evaluation of the merits of options. The framework aims to achieve the primary objective of the evaluation, which is to maximise the fulfilment of flow regimes that are required to sustain and/or enhance environmental values. In addition to meeting this primary objective, the assessment framework captures the feasibility, robustness, confidence and secondary impacts associated with options. This chapter sets out the key principles that underpin this framework and builds on the concepts set out in Chapter 8, namely the effectiveness and efficiency of the option packages.

9.2 Key assessment criteria

As outlined in Chapter 8, the primary objective of this project is to **identify a suite of options which deliver the maximum fulfilment of environmental flow recommendations.** Individual options were assessed in terms of their (1) effectiveness and (2) efficiency in achieving conformance with environmental flow recommendations prior to developing packages of options.

The second phase of the assessment process examines other criteria that are important is assessing the overall merit of individual options and option packages, specifically:

- **Feasibility-** The extent to which the option is technically proven in a similar context and practically deliverable.
- **Robustness-** The extent to which the option is able to cope with changes to environmental flow requirements and can operate effectively as a standalone option.
- **Confidence-** The quality of information underpinning option scoping and evaluation.
- **Secondary Impacts-** The extent to which the option creates secondary impacts

The use of these criteria in assessing options is described below in detail. It is, however, important to note that in undertaking the option assessments it has been assumed that:

- environmental benefits will be delivered by fulfilling the specified environmental flow regimes;
- the flow regimes that currently characterise the rivers and reaches of concern will be maintained in future (ie they are not vulnerable to the effects of climate change, variability in watertables, changes in irrigation water demand, or water trading);
- the water is available in storage and on demand to deliver the environmental flow components as appropriate to each option or package of options;
- options have been designed to maintain the current level of service to existing users unless explicitly stated otherwise;

- options have been designed to maintain existing operating rules unless stated otherwise (eg changing flooding operating rules);
- the required lead time associated with option implementation is not such that it would annul any potential benefits gained from delivery of environmental flows; and
- legal barriers to option implementation are not prohibitive (eg the need to obtain EPBC approvals, the conditions set out in the *Murray Darling Basin Agreement*).

Clearly, if these assumptions are violated then it would be appropriate to reconfirm the relative merit of the options identified within this report.

9.3 Feasibility

As outlined above, it is important to examine a number of additional criteria in order to assess the likely usefulness of any option or package of options. The first of these is the feasibility of options. Feasibility can be considered in two ways:

Criterion	Description	Yes	..	No
Technically feasible	a) Technologies and processes anticipated for use in implementing the option(s) are proven within a similar operational context, preferably within Victoria, thus minimising the risk of project failure and the security of investment.			
Practically deliverable	b) The option does not rely on third party participation that cannot be guaranteed. It is important to distinguish between fact and community resistant which has been incorporated as a secondary impact. In this instance the delivery of the option is *reliant* on actions by a third party(s).			

If either of these criteria are not met, then the viability and feasibility of the proposed option(s) would need to be questioned and additional investigations undertaken before proceeding further with that option(s).

9.4 Robustness of options

Options to delivery environmental flow components will be implemented individually or in packages over time. Circumstances may change (such as the availability of water, government funding, etc) that will require reconsideration of the merit of remaining options and their synergies with options that may have already been implemented. It is therefore worthwhile considering the relative robustness of options, for which two key criterion have been identified.

Criterion	Description	Yes	...	No
Robustness	a) Option can deliver a **range of flows** in future, providing adaptability should there be any refinement in the environmental flow recommendations. b) Option can deliver the specified flows **independently** and is not reliant on some other condition in order to achieve conformance.			

Robustness is an important criterion is there is considerable uncertainty around environmental flow recommendations or if the implementation of options will be staged.

9.5 Confidence

The quality of the information underpinning option scoping is variable. It is important to be aware of the level of confidence or certainty that exists regarding the reliability of the information upon which the option assessment has been made.

Criterion	Description	Yes	...	No
Confidence	a) Option has been developed and assessed based on supporting information which is available, accurate and can be independently verified.			

The confidence flag has been designed to inform decision makers of the need for more research into an option before committing to its implementation. In light of this low-confidence should not be considered a 'showstopper.'

9.6 Secondary impacts and consequences

In fulfilling the primary objective – that is, delivery of environmental flow components – it is possible that a range of flow-on or secondary impacts could arise. While they may not outweigh the primary benefit being delivered, they are important to consider in selecting and/or refining the approach to implementing an option or package of options. Each of the options selected for packaging have been evaluated in terms of their secondary impacts.

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	Criteria is achieved	*Impact is generally short-term and localised*	*Impact is generally larger, more wide spread, enduring*
Criteria	Yes	...	No
Low impacts on habitat			
Minimal increases in water losses			
Low energy consumption			
Low levels of flooding of urban areas			
Low levels of flooding of agricultural land			
Low levels of degradation of water quality			
No disruption of water delivery other users			
Low levels of disruption of recreation and tourism values			
Low levels of community resistance			
Low impacts on habitat			
Low levels of impact on built and cultural heritage			

9.7 Consolidated information on the assessed options

Each of the options is presented with summary tables as follows. This combines the approaches set out in both this and the preceding chapter. This table forms an interactive tool whereby users are able to select combinations of options and calculate the flow components which would be delivered and the corresponding technical feasibility, robustness and confidence ratings.

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All Options			FLOW COMPONENT								FEASIBILITY		ROBUSTNESS			SECONDARY IMPACTS								Comment
			SL	SF	WL	WF	WB	EFFECTIVENESS	$ million	EFFICIENCY	Technically Feasible	Practical Deliverability	Flexibility	Independence	CONFIDENCE	Low impacts on habitat	Low energy consumption	Low levels of flooding of urban areas	Low levels of flooding of agricultural land	Low levels of degradation of water quality	No disruption of water delivery other users	Low levels of disruption of recreation and tourism values	Low levels of community resistance	
✓	C1S1	Modify Malmsbury outlet to enable releases between 15 and 45 ML/d	2	1	2	0	0	0.50	$0.01	50.00	✓	✓	–	✓	✓	✓	✓	✓	✓	✓	–	✓	✓	
✓	C1S2	Increase release capacity from Coliban Channel to River to 200 ML/d	0	2	0	0	0	0.20	$0.08	2.50	✓	✓	–	✓	✓	✓	✓	✓	✓	✓	–	✓	✓	Possibly some disruption to urban water supply
	C1W1	Construct pondage downstream of Malmsbury Reservoir	2	2	2	2	1	0.90	$5.00	0.18	✓	✓	✓	✓	✗	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	
	C1W2	Increase capacity of Malmsbury outlet to 700 ML/d	2	2	2	2	1	0.90	$4.00	0.23	✓	✓	✓	✓	✓	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	
✓	C1W3	Modify Malmsbury operation, including additional releases from upstream storages	0	0	0	2	1	0.30	$0.00		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	–	✓	✓	Possibly some disruption to urban water supply
✓	C1W4	Modify Malmsbury release patterns to produce bankfull flow recommendations	0	0	0	0	2	0.20	$0.00		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	
	Selected Package		2	2	2	2	2																	
	Selected Cost		$				0.09	million																

Importantly, the fact that an option is not robust, is difficult to implement, has been developed on an incomplete set of information or has adverse secondary impacts does not necessarily mean that it should not be implemented. This assessment process is designed to flag potential challenges associated with option implementation. More detailed assessment would be necessary to determine whether these challenges can be overcome.

9.8 Goulburn Case Study

In order to test the option assessment and packaging framework set out in above a workshop was held to discuss the implications within the Goulburn system. The assessment framework for the Goulburn system is shown in **Figure 6**.

It can be seen that there are only two options which deliver summer low flows in the Eildon to Goulburn Weir reach, option G1S1 (pipeline from Eildon to Goulburn Weir) and option G1S7 (on-farm and regional winterfill storages):

- Option G1S1 has a very low efficiency due to the high cost associated with implementing the option. It is not flexible due to the fact that the capacity of the option to deliver changed environmental flow recommendations is limited by the carrier capacity. It scores poorly on the impacts on habitat and built and cultural heritage due to the corridor route. Finally, it was assigned average scores on the impact on recreational and tourism and community resistance due to the localised impact that it is likely to have on fishing and the landowners along the corridor route.
- Option G1S7 is more efficient than option G1S1. Despite this it is still not very cost efficient. It scores low on practical deliverability as it relies on third party participation. It will increase losses within the system due to the increased surface area associated with a high number of

small storages. It will also increase energy consumption within the systems as individual storages may have pumps.

There are a number of options which will deliver spring flows in the reach between Eildon and Goulburn weir. These options all relate to modified operation of Eildon weir and also deliver environmental flows to downstream reaches. The effectiveness of options in delivering flows relates to the magnitude of the releases which is likely to be governed by water availability rather than any physical constraint (see **Figure 6**). All options delivering spring flows in the reach between Eildon and Goulburn Weir are highly efficient as there is no capital cost associated with their implementation. The key issue is flooding of both urban and rural areas which is likely to trigger community resistance unless actively managed. It is possible that this secondary impact could be mitigated through flood management measures (and therefore increased costs).

The most effective and efficient option package for the Goulburn system is G1S7 and GMSp3. This package is capable of delivering the full suite of environmental flows within the system. Despite this, the cost associated with this package is high at three billion dollars. This cost is exclusively associated with the delivery of summer low flows between Eildon and Goulburn Weir. In light of this, the requirement for third party participation and the increase in energy use and system losses associated with an increase in on-farm and regional storages it is possible that decision-makers would elect to forego the delivery of this flow component. Such a decision would marginally decrease the effectiveness of the option package but dramatically increase the package efficiency. As outlined above, it is not possible to fully package or assess options until the availability of water for the delivery of environmental flows has been assessed and options to achieve this are included in the packaging process.

9.9 Broader catchment trends not included in this assessment

There are a number of broader catchment trends that may affect the capacity to achieve environmental flows. These trends have not been included in the assessment due to inadequate information and incomplete knowledge regarding the likely impact on options. None-the-less it is important to acknowledge that they are likely to have an impact on water availability and therefore the delivery of environmental flows. The trends include:

- **Climate change-** it is now widely accepted that climate change constitutes one of the biggest threats to water availability. It has been estimated that climate change could potentially reduce streamflows by 15% over the next 50 years.
- **Afforestation -** plantation forestry is an increasingly significant land use in Australia. Trees have been demonstrated to use more water than non-irrigated pastures or crops. This means that there is less run-off from catchments and therefore reduced streamflows.

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- **Groundwater extraction -** groundwater extraction has increased over the last twenty years. Studies have indicated that groundwater pumping has the potential to impact on downstream surface water reliability. In connected groundwater-surface water systems there can be a lag time of days to sometimes decades between the commencement of groundwater extraction and the time at which its impact is evident in streamflows. This means that the impacts of historic groundwater pumping could be increasingly impacting on streamflows.
- **Changes to irrigation management -** as discussed throughout this report, irrigation is one of the major reasons for river regulation. The need for irrigated agriculture is driven by the demand for food, which is intrinsically linked to population growth, global economic trends and other factors. Significant changes to irrigated agriculture in Australia would have a major impact on instream flows. In particular, the creation of a water market and the unbundling of water rights have the potential to dramatically change the footprint of the industry. Similarly, the impact of climate change and possible lower rainfall could mean an increased need to water crops through irrigation.
- **Farm Dams -** farm dams reduce streamflow by intercepting runoff, increasing losses to evaporation and enabling the use of stored water. There is strong evidence to suggest that farm dam numbers are increasing following the significant droughts in Australia. Uncontrolled increases in farm dams have the potential to reduce streamflows.
- **Bushfires -** although bushfires are a natural phenomena they can have a major impact on streamflow. When a bushfire sweeps through a landscape it destroys vegetation and as the vegetation regenerates the plant water requirements change, potentially affecting the volume of runoff into streams.

9.10 Salinity Impacts

The impacts of changes to the flow regimes in the basins under consideration may result in changes to the salinity within the valleys themselves and also downstream impacts on the River Murray. This section outlines the issues involved and potential impacts in major reaches of the study area.

9.10.1 Background

As the Goulburn, Broken, Campaspe and Loddon basins lie within the Murray Darling Basin, actions need to be considered with respect to the Basin Salinity Management Strategy (BSMS) 2001 - 2015 (MDBMC, 2001). A key feature of the BSMS is the adoption of end of valley targets as a means of measuring progress towards achieving the Strategy's objectives. The end-of-valley target sites, documented in SKM (2005), which are relevant to this project are as follows:

- Goulburn River at Goulburn Weir;
- Campaspe River at Campaspe Weir; and,
- Loddon River at Laanecoorie Weir.

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The end of basin target site is the River Murray at Morgan.

Potential salinity impacts of actions taken to deliver environmental flow requirements will depend on the location, timing and volume of changes to the existing flow regime. As quantifying or modelling flows has not been within the scope of this study, salinity impacts can not be quantified, however, potential salinity impacts of options to achieve environmental flow objectives are discussed broadly in the sections below.

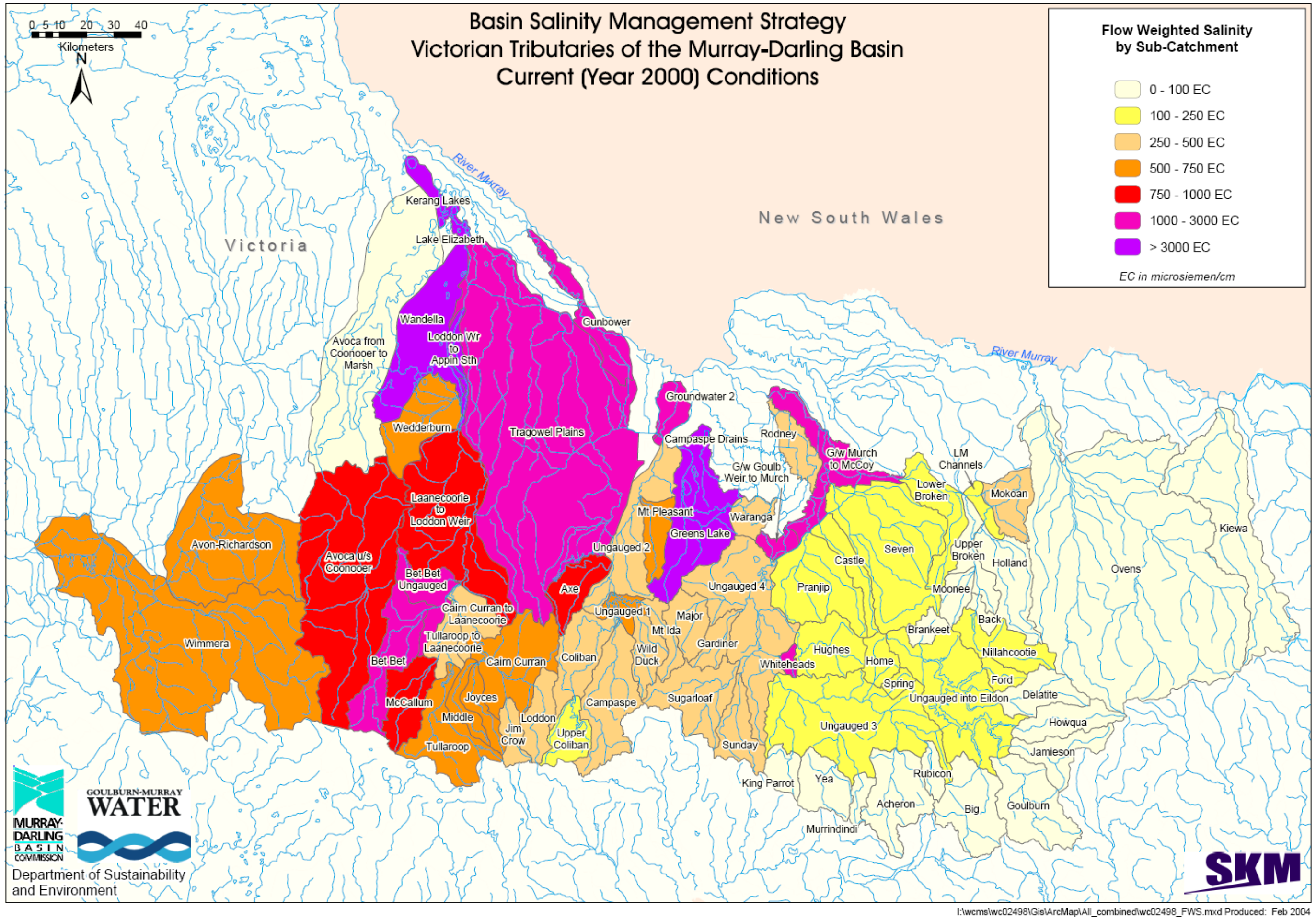
9.10.2 Overview of stream salinity in the study area

The salinity of tributary inflows in the Goulburn, Broken, Campaspe and Loddon catchments can be described as generally very low in the south east of the study area and increases the further west and north in the study area that the tributary is located. This general pattern can be seen in Figure 5 below. The flow weighted salinity (FWS) of tributaries in the far south east (eg to the east and south of Lake Eildon) are less than 100 EC. The tributaries in the South West Goulburn and most of the Campaspe catchment upstream of Lake Eppalock have FWS in the range from 250-500 EC. In the Loddon catchment the FWS of tributaries rises from the range of 250 – 500 EC in the east to over 1,000 EC in the west in the Bet Bet Creek catchment.

The median salinity of storages also reflects the location of the tributaries which flow into them. The median reservoir salinity has been calculated based on the Victorian Tributary flow and salinity models for the MDBC Basin Salinity Management Strategy (BSMS) benchmark period from 1975 – 2000 and is presented in the Table 20.

- **Table 20 Median Reservoir Salinity**

Reservoir	Median EC
Lake Eildon	60
Waranga Basin	110
Lake Eppalock	410
Cairn Curran Reservoir	510
Tullaroop Reservoir	690
Laanecoorie Reservoir	790



- **Figure 5 Basin Salinity Management Strategy (Current Conditions) Source (SKM, 2004)**

9.10.3 Potential Impacts on the River Murray

The impacts on the River Murray of the implementation of environmental flow recommendations are very difficult to predict. The reason for this is that it is dependent on how the River Murray system is operated in response to (or in conjunction with) the flow contributions from the Victorian tributaries and also where the additional Victorian environmental flows are used.

For example, if the additional flow is utilised for Gunbower Forest, the volume of return flow, together with any salt mobilisation within the Forest would be required to estimate salinity impacts. If the flows were to contribute to the flow to the Murray Mouth, then salinity impacts along the River Murray length would need to be included. If, for example, the Victorian Living Murray contributions were timed to “piggy back” on a Barmah Millewa flood release from Lake Hume, then the salinity impact will be quite different to the effect if the River Murray was fully regulated at the time.

In order to assess the potential salinity impacts on the River Murray with more certainty, the timing, volumes and source of all flows would be required together with operational rules for the River Murray system. However, with regard to the general nature of proposed changes to the flow regime, some general comments on potential effects have been presented in the subsections of each of the downstream reaches for the Goulburn, Broken, Campaspe and Loddon catchments below.

9.10.4 Goulburn

9.10.4.1 Upstream of Goulburn Weir

The impact of increasing flows in the winter and spring in the reach of the Goulburn River between Lake Eildon and Goulburn Weir would be expected to reduce salinity of flows during this time as more of the total flow is sourced from Eildon which has salinity in the order of 60 EC, compared to some of the south west Goulburn tributaries of 200 EC.

Conversely if summer flows are reduced through decreases in releases from Eildon, salinities in this reach would be expected to increase as the contribution to the total flow of higher salinity tributaries would be greater.

9.10.4.2 Downstream of Goulburn Weir

The salinity of flows downstream of Goulburn Weir is currently governed by the flow regulated or spilled over Goulburn Weir and saline groundwater inflows in this reach which are described in SKM (2002b). The impact of increasing flows in the spring months will be to decrease the salinity of flows as a result of greater flow from Eildon passing downstream of the weir and also higher river levels may result in less groundwater discharge to the river.

Increasing flows during summer in this reach may decrease salinity slightly due to less groundwater discharge. However, the greater impact on salinity in this reach would be dependent on changes to the flow regime upstream of Goulburn Weir. If flows in the Goulburn River upstream of Goulburn Weir were reduced, the salinity would most likely increase and hence the salinity in the reach downstream of Goulburn Weir would also increase.

The salinity impact on the River Murray will depend on the relative salinities of the Goulburn River and the River Murray. This is very difficult to estimate as the source, volume and timing of the changes to the flow regime has not been assessed as it is not within the scope of this study. It will also depend on whether the additional water is consumed in the River Murray (say in a wetland) or flows through to the sea.

9.10.5 Broken Creek

Greater releases to Broken Creek from either the Murray Valley irrigation supply system or the East Goulburn Main Channel would be likely to decrease the salinity of the creek.

There would potentially be two effects which would determine whether the impact of supplying additional water to the Broken Creek would be an increase or a decrease in salinity in the River Murray.

The effect which would be expected to increase salinity in the River Murray is that the salinity of flows in Broken Creek would be less and hence the volumes of salt diverted by private diverters would be less. Therefore, greater salt load would reach the River Murray.

However, if the additional flow is in addition to existing flows entering the River Murray rather than as a substitution of existing flows, the dilution effect of these flows may still result in an overall average decrease in salinity in the River Murray.

9.10.6 Campaspe

9.10.6.1 Malmsbury to Eppalock

The flow weighted salinity of the Upper Coliban River upstream of Malmsbury is the lowest of the Campaspe basin tributaries presented in the
Figure 5. Therefore any actions which involve additional flow from Malmsbury to Lake Eppalock would be likely to decrease salinity during that period, while actions which decrease the flow from Malmsbury to Eppalock may increase salinity during this period.

9.10.6.2 Eppalock to Campaspe Weir

The reach of the Campaspe River from Lake Eppalock to Campaspe Weir is characterised by tributaries with quite high salinity such as Axe Creek and Mt Pleasant Creek. Any action which changes the relative proportions of released flow from Lake Eppalock to the tributary inflow will impact on the salinity in those times.

9.10.6.3 Campaspe Weir to Campaspe Siphon

The salinity of flow in this reach is influenced by the volume of flow required to pass Campaspe Weir for either minimum or low flow requirements or for the Campaspe Supplement to the Waranga Western Channel. The greater the regulated flow supplied from Lake Eppalock, compared to the tributary inflow, the lower (and less variable) the salinity in this reach is likely to be.

9.10.6.4 Campaspe Siphon to River Murray

The salinity of flows in this reach of the Campaspe River could be significantly reduced by supplying flow from the Waranga Western Channel. It is also influenced by Campaspe West Drainage Diversion which includes rules on when drainage may be discharged to the Campaspe River and when it may be discharged to the Waranga Western Channel.

Due to the relatively high salinity of Campaspe catchment flows, the impact on the River both in spring and during summer is likely to be an increase to salinity in the River Murray. The extent and even direction of the impact may depend on sources of flows for provision of environmental flows and operation of the River Murray system.

9.10.7 Loddon

9.10.7.1 Tullaroop Creek Downstream of Tullaroop Reservoir

In the reach of Tullaroop Creek from Tullaroop Reservoir to Laanecoorie Reservoir, flow from McCallum Creek which has a flow weighted salinity in the range of 750-1,000 EC mixes with releases from Tullaroop Reservoir which have median EC of around 700 EC. If greater flows are released from Tullaroop Reservoir during spring, the salinity may be increased or decreased during different times during the flow event. This is because of the mixing of flows in Tullaroop Reservoir providing less variability in salinity compared to the less regulated catchment of McCallum Creek.

9.10.7.2 Cairn Curran to Laanecoorie

The reach of the Loddon River from Cairn Curran to Laanecoorie does not have any significant tributaries until it reaches the Laanecoorie Weir pool where Tullaroop Creek and Bet Bet Creek join. Therefore salinity in this reach is unlikely to be significantly affected assuming some flow from Cairn Curran is still released at all times into this reach. However, changes to the operation in Cairn Curran may result in the salinity in this reach becoming more variable.

9.10.7.3 Laanecoorie to Loddon Weir

Laanecoorie Reservoir provides a dampening effect on salinity spikes in the Loddon River due to highly saline inflows from the Bet Bet Creek catchment. Any changes to the flow regime which impact on the relative proportion of flow in this reach from tributaries (including Bet Bet Creek) will affect the salinity of flows in this reach. If flows in the spring are increased, this is likely to decrease the salinity of flows reaching Loddon Weir increasing spring time flows.

9.10.7.4 Loddon Weir to Kerang Weir

The impact of actions to increase both the summer and winter flows in this reach could be quite significant. The impact of supplying substantially higher summer flows in particular, would potentially have high impacts on salinities within the Kerang Lakes. This is because the supply to the Kerang Lakes during the irrigation season is predominantly via Pyramid Creek which flows into the Kerang Weir pool where it mixes with Loddon River water.

Another significant influence on salinity in this reach is the mixing of flows from the Waranga Western Channel which has salinity in the order of 100-200 EC with the flows from the Loddon which may be in the order of 700 EC. Any action which results in greater flow from the Waranga Western Channel mixing at Loddon Weir would potentially reduce salinity in the Loddon downstream of Loddon Weir.

9.10.7.5 Kerang Weir to River Murray

The reach from Kerang Weir to the River Murray may also be influenced significantly by a changed flow regime to provide environmental flows for the same reasons as the reach of the Loddon River from Loddon Weir to Kerang Weir.

The impact on the River Murray of additional flows in the lower reaches of the Loddon catchment in both spring and summer is likely to be an average increase. This is due to the relatively high salinities of flows in the Loddon catchment. The extent of the impact will depend not only on the change in salinity but also the change in salt load reaching the River Murray either from the Loddon River directly or indirectly by return flows through the Kerang Lakes system.

9.10.8 Summary of Potential Salinity Impacts

The table below presents a summary of the potential salinity impacts of changes to the flow regime grouped by river reaches. The changes to the flow regime have been grouped into two general classifications: impact of changed spring flows and impact of changed summer flows. Generally all the flow recommendations require increases in flows in winter and spring. Whether a reach is currently used to deliver large volumes of water for irrigation during summer will govern whether an increase or decrease in flow in that reach is required to meet environmental flow recommendations. This requirement has been included in the reach description.

Table 21 Potential Salinity Impacts of Changes to the Flow Regime

River Basin	Reach	Impact of changed Spring Flows	Impact of changed Summer flows
Goulburn	Upstream of Goulburn Weir (Increased Spring flows, Decreased Summer Flows)	Decrease	Increase
	Downstream of Goulburn Weir (Increased Spring flows, increased Summer Flows)	Decrease	Decrease
	Impact on River Murray	Unknown	Unknown
Broken Creek	Broken Creek downstream of Katamatite	Decrease	Decrease
	Impact on River Murray	Unknown	Unknown
Campaspe	Malmsbury to Eppalock (Increased Spring flows, increased Summer Flows)	Decrease	Decrease
	Eppalock to Campaspe Weir (Increased Spring flows, Decreased Summer Flows)	Decrease	Increase
	Campaspe Weir to Campaspe Siphon (Increased Spring flows, increased Summer Flows)	Decrease	Unknown
	Campaspe Siphon to River Murray (Increased Spring flows, increased Summer Flows)	Decrease	Unknown
	Impact on River Murray	Increase	Increase
Loddon	Tullaroop Creek Downstream of Tullaroop Reservoir (Increased Spring flows, Decreased Summer Flows)	Unknown	Unknown
	Cairn Curran to Laanecoorie (Increased Spring flows, Decreased Summer Flows)	Decrease	Increase
	Laanecoorie to Loddon Weir (Increased Spring flows, Decreased Summer Flows)	Decrease	Increase
	Loddon Weir to Kerang Weir (Increased Spring flows, increased Summer Flows)	Decrease	Increase
	Kerang Weir to River Murray (Increased Spring flows, increased Summer Flows)	Decrease	Increase
	Impact on River Murray	Increase	Increase

In summary, the changes to the flow regime in the Loddon and Campaspe may have significant salinity impacts on the relevant end of valley sites and also on the River Murray due to the relatively high salinity of flows in these catchments.

Changes to the flow regime in the Goulburn River and Broken Creek are more difficult to determine whether the impact will be an increase or decrease on average. This is due to the lower difference between salinity in these streams and the River Murray (and the potentially very large volumes of water involved in the Goulburn River flow recommendations).

The extent of salinity impacts in all of the catchments will be governed by the location, timing and volume of changes to the existing flow regime. This has not been assessed in detail as part of the scope of this study and would need to be to estimate salinity impacts for any given change to the flow regime.

9.11 Option Assessment Tables and Selected Packages

Options were assessed on the basis of the assessment framework described in the preceding chapter and are shown in the following figures.

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9.11.1 Goulburn System Option Evaluation

- **Figure 6 Goulburn system all options**

All Options

OPTION	DESCRIPTION	FLOW COMPONENT: Eildon to Goulburn Weir SL	Eildon to Goulburn Weir SpO	Downstream of Goulburn Weir SpO	Living Murray SpL	Living Murray SpF	EFFECTIVENESS	Constraint Cost ($ million)	EFFICIENCY	FEASIBILITY: Technically Feasible	Practical Deliverability	ROBUSTNESS: Flexibility	Independence	CONFIDENCE
	Weight (%)	100	100	100	100	100								
G1S1	Pipeline from Eildon to Goulburn Weir	2	0	0	0	0	0.13	$ 23,000.00	0.000	✓	✓	✗	✓	✓
G1S2a	Pulse flows from Eildon - large amplitude	1	0	0	0	0	0.06	N/A		✓	✓	✗	✓	✗
G1S2b	Pulse flows from Eildon - small amplitude	1	0	0	0	0	0.06	$ -	1.000	✓	✓	✗	✓	✗
G1S3	Modified operation of Waranga Basin	0	0	0	0	0	0.00	$ -	1.000	✓	✓	✗	✓	✓
G1S4	Divert flows from Broken River into EGM	1	0	0	0	0	0.06	N/A		✓	✓	✗	✓	✓
G1S5	On-stream storage at Camp Hill	1	0	0	0	0	0.06	$ 100.00	0.001	✓	✓	✗	✓	✓
G1S6	Enlarge Waranga Basin	1	0	0	0	0	0.06	$ 5,000.00	0.000	✓	✓	✗	✓	✓
G1S7	On-farm and regional winterfill storages	2	0	0	0	0	0.13	$ 3,000.00	0.000	✓	✗	✓	✓	✓
G1S8	Use of Lake Cooper	0	0	0	0	0	0.00	N/A		✓	✓	✗	✓	✓
G1S9	New storage along East Goulburn Main Channel	1	0	0	0	0	0.06	$ 4,000.00	0.000	✓	✓	✗	✓	✓
G1S10	Interconnector from Yarrawonga to EGM	1	0	0	0	0	0.06	$ 200.00	0.000	✓	✓	✗	✓	✓
G1Sp1a	Modified Eildon operation (target release)	0	2	2	1	1	0.38	$ -	1.000	✓	✓	✓	✓	✓
G1Sp1b	Modified Eildon operation (modify target filling curves to optimise provision of environmental floods)	0	2	2	1	1	0.38	$ -	1.000	✓	✓	✓	✓	✓
G1Sp2	Pump into key wetlands	0	1	1	0	0	0.13	$ 2.50	0.050	✓	✓	✗	✓	–
G1Sp3	Construct weirs to direct flows into key wetlands	0	1	1	0	0	0.13	N/A		✓	✓	✗	✓	–
G1Sp4	Minimise harvesting of floods into Waranga Basin	0	0	1	1	1	0.19	$ -	1.000			✗		
GMSp1	Release from Eildon, plus flood management measures (December)	0	2	2	2	1	0.44	N/A		✓	✓	✓	✓	✓
GMSp2	Minimise harvesting of floods into Waranga Basin (July - Nov)	0	0	1	1	1	0.19	$ -	1.000			✗		
GMSp3	Release from Eildon plus flood management measures (higher standards than GMSp1)	0	2	2	2	2	0.50	$ -	1.000	✓	✓	✓	✓	✓
Selected Package														
Selected Cost		$			-				million					

OPTION	SECONDARY IMPACTS: Low impacts on habitat	Minimal increases in water losses	Low energy consumption	Low levels of flooding of urban areas	Low levels of flooding of agricultural land	Low levels of degradation of water quality	No disruption of water delivery other users	Low levels of disruption of recreation and tourism val…	Low levels of community resistance	Low levels of impact on built and cultural heritage	Comment
G1S1	✗	✓	✓	✓	✓	✓	✓	–	–	✗	Flexibility is reliant on carrier capacity. There is likely to be some impacts on habitat during construction. High adverse impacts on fishing and tourism.
G1S2a	✓	✓	–	✓	–	✓	✓	✓	✓	✓	Flexibility is reliant on irrigation demand. There is limited confidence that pulsing flows would deliver environmental benefit.
G1S2b	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	Possibly some environmental benefit.
G1S3	✓	–	✓	✓	✓	✓	–	✓	–	✓	This option does not deliver required flows.
G1S4	✓	✓	–	✓	✓	✓	✓	✓	–	✓	This option is only able to partially deliver summer low flows, Resistance.
G1S5	✗	✗	✓	✓	✓	✓	✓	✓	✗	✗	Flexibility is reliant on storage capacity.
G1S6	✗	✗	✓	✓	✓	✓	✓	✓	✗	✗	Flexibility is reliant on storage capacity.
G1S7	✓	✗	–	✓	✓	✓	✓	✓	✓	✓	Practical delivery is reliant on third party participation. Pumping likely to be required. Evaporation losses from storages.
G1S8	✓	–	✓	✓	✓	–	✓	✓	✓	✓	Option can not deliver recommended flows and is unlikely to be able to deliver flows into the future.
G1S9	–	✗	✗	✓	✓	✓	✓	✓	✗	–	Option can not deliver recommended flows and is unlikely to be able to deliver flows into the future.
G1S10	✗	–	✓	✓	✓	✓	✓	✓	–	–	Option can not deliver recommended flows and is unlikely to be able to deliver flows into the future.
G1Sp1a	✓	✓	✓	✗	✗	✓	✓	✓	✗	✓	There is a risk of nuisance flooding to agriculture. Extra flood damages for the towns of Molesworth, Thornton and Seymour have been estimated to be $23,000,000.
G1Sp1b	✓	✓	✓	✗	✗	✓	✓	✓	✗	✓	Some flooding may occur. Extra flood damages for the towns of Molesworth, Thornton and Seymour have been estimated to be $23,000,000.
G1Sp2	✓	✓	✗	✓	✓	✓	✓	✓	✓	✓	This option would not deliver required flows but may give rise to localised environmental benefit in wetlands.
G1Sp3	✗	–	✓	✓	–	✓	✓	–	✗	–	This option would not deliver required flows but may give rise to localised environmental benefit in wetlands.
G1Sp4	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	This option would not deliver all required flows.
GMSp1	✓	✓	✓	✗	✗	✓	✓	✓	–	✓	Some flooding may occur and would need to be managed. Note that tributary flows may replace releases from Eildon.
GMSp2	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	This option would not deliver all required flows. Note that tributary flows may replace releases from Eildon.
GMSp3	✓	✓	✓	✗	✗	✓	✓	✓	–	✓	Modified releases of this magnitude may cause flooding to agricultural land and urban centres, this would need to be pro-actively managed. In addition large releases from Eildon may impact on security of supply to other users. Capital costs associated with flood protection not included.

Note: This table has been prepared as a part of preliminary option assessment only. Option impact and cost should be subject to detailed investigation before proceeding.

Option cost estimates are coarse and preliminary only and in particular do not include the cost of operation, maintenance, consultation, investigation, design and secondary impact mitigation

LEGEND	
2	Full compliance with environmental flow component
1	Partial compliance with environmental flow component
✓	Option complies with stated criteria
–	Option does not comply with stated criteria. Impact of non-compliance is short term/ localised.
✗	Option does not comply with stated criteria. Impact of non-compliance is long term/ widespread.

SKM

9.11.2 Broken System Option Evaluation

- **Figure 7Broken system all options**

All Options

ID	Option	IL (FLOW COMPONENT)	SpF (FLOW COMPONENT)	EFFECTIVENESS	Constraint Cost ($ million)	EFFICIENCY	Technically Feasible (FEASIBILITY)	Practical Deliverability (FEASIBILITY)	Flexibility (ROBUSTNESS)	Independence (ROBUSTNESS)	CONFIDENCE	Low impacts on habitat (SECONDARY IMPACTS)	Minimal increases in water losses	Low energy consumption	Low levels of flooding of urban areas	Low levels of flooding of agricultural land	Low levels of degradation of water quality	No disruption of water delivery other users	Low levels of disruption of recreation and tou…	Low levels of community resistance	Low levels of impact on built and cultural her…	Comment
	Weight	100	100																			
BI1	Interconnector from Yarrawonga to Broken Creek (100 ML/d)	2	0	0.50	$15.00	0.033	✔	✔	–	✔	✔	–	✕	✔	✔	✔	✔	✔	✔	–	–	Flexibility is reliant on carrier capacity. There is potential community resistance to new large channel which will traverse property. Potential cultural heritage and habitat impacts.
BI2a	Increased capacity from Murray Valley - enlarge channels	2	0	0.50	$12.00	0.042	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	Flexibility is reliant on carrier capacity.
BI2b	Increased capacity from Murray Valley - purchase channel capacity	1	0	0.25	$9.00	0.028	✔	✔	✕	✔	–	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	This option relies on channel capacity being available for purchase.
BI3a	Increased capacity from Shepparton - augment EGM	2	0	0.50	$10.00	0.050	✔	✔	–	✔	✔	–	✔	✔	✔	✔	✔	✔	✔	✔	✔	This option would deliver the required flows but would not be able to respond quickly to azolla blooms.
BI3b	Increased capacity from Shepparton - purchase EGM channel capacity	1	0	0.25	$9.00	0.028	✔	✔	✕	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	This option would depend on the availability of channel capacity and flexibility would be limited by carrier capacity.
BI4	Additional capacity from Upper Broken Creek	1	0	0.25	$0.00	1.000	✔	✔	✕	✔	✔	–	✔	✔	✔	✔	✔	✔	✔	✔	–	
BSp1	Interconnector from Yarrawonga to Broken Creek (500 ML/d)	2	2	1.00	$20.00	0.050	✔	✔	✔	✔	✔	–	✔	✔	✔	✔	✔	✔	✔	–	–	The construction of an interconnector would impact on habitat along the corridor. Transferring water from Yarrawonga to Broken Creek would require pumping and therefore energy consumption. The transfer of water from Yarrawonga to the Broken system would impact on water quality.
BSp2	Offline storage near upstream end of Azolla affected reach	2	2	1.00	$30.00	0.033	✔	✔	✔	✔	✔	–	–	–	✔	✔	✔	✔	✔	✔	–	
BSp3a	Increased capacity from Murray Valley - enlarge channels	2	2	1.00	$12.00	0.083	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	–	✔	✔		There are potential impacts to other users associated with this option.
BSp3b	Increased capacity from Murray Valley - purchase channel capacity	1	0	0.25	$9.00	0.028	✔	✔	✕	✔	–	–	✔	✔	✔	✔	✔	✔	✔	✔	–	
BSp4a	Increased capacity from Shepparton - augment EGM	2	2	1.00	$27.00	0.037	✔	✔	✔	✔	✔	–	✔	✔	✔	✔	✔	✔	✔	✔	–	
BSp4b	Increased capacity from Shepparton - purchase EGM channel capacity	1	0	0.25	$27.00	0.009	✔	✔	✕	✔	–	–	✔	✔	✔	✔	✔	✔	✔	✔	–	
BSp5	Additional capacity from Upper Broken Creek	0	0	0.00	$0.00	1.000	✕	✔	✔	✔	✔	–	✔	✔	✔	✔	✔	✔	✔	✔	–	This option was not considered feasible

Selected Package

Selected Cost $ - million

Note: **This table has been prepared as a part of preliminary option assessment only. Option impact and cost should be subject to detailed investigation before proceeding.**

Option cost estimates are coarse and preliminary only and in particular do not include the cost of operation, maintenance, consultation, investigation, design and secondary impact mitigation

LEGEND	
2	Full compliance with environmental flow component
1	Partial compliance with environmental flow component
✔	Option complies with stated criteria
–	Option does not comply with stated criteria. Impact of non-compliance is short term/ localised.
✕	Option does not comply with stated criteria. Impact of non-compliance is long term/ widespread.

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9.11.3 Coliban System Option Evaluation

▪ **Figure 8 Coliban River all options**

All Options

		SL	SF	WL	WF	WB	EFFECTIVENESS	Constraint Cost ($ million)	EFFICIENCY	Technically Feasible	Practical Deliverability	Flexibility	Independence	CONFIDENCE	Low impacts on habitat	Minimal increases in water losses	Low energy consumption	Low levels of flooding of urban areas	Low levels of flooding of agricultural land	Low levels of degradation of water quality	No disruption of water delivery other users	Low levels of disruption of recreation and tourism valu	Low levels of community resistance	Low levels of impact on built and cultural heritage	Comment
		FLOW COMPONENT								FEASIBILITY		ROBUSTNESS			SECONDARY IMPACTS										
	Weight	100	100	100	100	100																			
C1S1	Modify Malmsbury outlet to enable releases between 10-15 and 45 ML/d	2	1	2	0	0	0.50	$0.01	50.0	✔	✔	–	✔	✔	✔	✔	✔	✔	✔	✔	–	✔	✔	?	Possibly some issues assoc
C1S2	Increase Coliban Main Channel outfall capacity to Coliban River to 200ML/d	0	2	0	0	0	0.20	$0.15	1.3	✔	✔	–	✔	✔	✔	✔	✔	✔	✔	✔	–	✔	✔	?	Possibly some disruption to urban water supply
C1W1	Construct pondage downstream of Malmsbury Reservoir	2	2	2	2	1	0.90	$5.00	0.2	✔	✔	✔	✔	–	–	–	✔	✔	✔	✔	✔	✔	–	–	Potential issues regarding feasible location of storage.
C1W2	Increase capacity of Malmsbury Reservoir outlet to 700 ML/d	2	2	2	2	1	0.90	$4.00	0.2	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	?	
C1W3	Modify Malmsbury operation, including additional releases from upstream storages	0	0	0	2	1	0.30	$0.00	1.0	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	–	✔	✔	✔	Possibly some disruption to urban water supply, due to releases from upstream storages.
C1W4	Modify Malmsbury release patterns to produce bankfull flow recommendations	0	0	0	0	2	0.20	$0.00	1.0	–	✔	✕	✔	✕	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	Relies on co-incident tributary inflows. Volume of reservoir above spillway gates may also be an issue.
Selected Package																									
Selected Cost		$				-	million																		

Note: **This table has been prepared as a part of preliminary option assessment only. Option impact and cost should be subject to detailed investigation before proceeding. Option cost estimates are coarse and preliminary only and in particular do not include the cost of operation, maintenance, consultation, investigation, design and secondary impact mitigation**

LEGEND	
2	Full compliance with environmental flow component
1	Partial compliance with environmental flow component
✔	Option complies with stated criteria
–	Option does not comply with stated criteria. Impact of non-compliance is short term/ localised.
✕	Option does not comply with stated criteria. Impact of non-compliance is long term/ widespread.

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9.11.4 Campaspe System Option Evaluation and Packages

- **Figure 9 Campaspe system all options**

All Options — FLOW COMPONENT

		Eppalock to Campaspe Weir					Campaspe Weir to Siphon				Siphon to Murray					Living Murray					
		SCTF	SL	SF	WB	WO	SL	SF	WB	WO	SL	SF	WL	WH	WB	WH	WB	EFFECTIVENESS	Constraint Cost ($ million)		EFFICIENCY
	Weight	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100				
C2S1	Pipeline or channel from Eppalock to Campaspe Weir	2	2	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0.19	$	160.00	0.00
C2S2	On farm and regional winter-fill storages	2	2	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0.19	$	350.00	0.00
C2S3	Purchase CID and PD entitlements for sale to Bendigo	2	2	1	0	0	1	1	0	0	2	2	0	0	0	0	0	0.34	$	59.00	0.01
C2S4	Supply CID and PDs downstream of Campaspe Siphon from WWC	1	1	1	0	0	1	1	0	0	0	0	0	0	0	0	0	0.16	$	65.00	0.00
C2S5	Offline storage near Campaspe Weir, filled in winter	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0.09	$	750.00	0.00
C2S6	Use of Green's Lake	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0.09	$	65.00	0.00
C2S7	Pulse discharges from Lake Eppalock	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0.03	$	-	1.00
C2W1	Operate Lake Eppalock differently	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00	$	-	1.00
C2W2	Increase capacity of Lake Eppalock outlet works to 12,000ML/d at lower storage level	0	0	0	2	2	0	0	2	2	0	0	0	0	2	2	1	0.41	$	25.00	0.02
C2W3	Construct pondage downstream of Lake Eppalock	0	0	0	2	2	0	0	2	2	0	0	0	0	2	2	1	0.41	$	15.00	0.03
C3S1	Pipeline or channel from Campaspe Weir to Campaspe Siphon	0	0	0	0	0	2	2	0	0	0	0	0	0	0	0	0	0.13	$	27.00	0.00
C3S2	On-farm winterfill storage	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0.06	$	7.50	0.01
C3S3	Purchase of all PD entitlements downstream of Campaspe Weir for sale to Bendigo or upstream irrigators	0	0	0	0	0	1	1	0	0	2	2	0	0	0	0	0	0.19	$	4.50	0.04
C3S4	Supply PD demand from adjacent channel system	0	0	0	0	0	1	1	0	0	2	2	0	0	0	0	0	0.19	$	4.00	0.05
C3W1	Modify Eppalock releases to piggyback on high tributary inflows	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00	$	-	1.00
C4S1	Pipeline of channel from Campaspe siphon to River Murray	0	0	0	0	0	0	0	0	0	2	2	0	0	0	0	0	0.13	$	7.00	0.02
C4S2	On-farm winterfill storages	0	0	0	0	0	1	1	0	0	2	2	0	0	0	0	0	0.19	$	6.00	0.03
C4S3	Purchase of reach PD entitlements for sale to Bendigo or upstream irrigators	0	0	0	0	0	1	1	0	0	2	2	0	0	0	0	0	0.19	$	3.00	0.06
C4W1	Supply from WWC	0	0	0	0	0	0	0	0	0	0	0	2	2	1	2	2	0.28	$	-	1.00
M1W1	Increase outlet capacity of Eppalock to 2,200 ML/d at lower storage levels	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0.06	$	2.00	0.03

	FEASIBILITY		ROBUSTNESS			SECONDARY IMPACTS										COMMENT
Option	Technically Feasible	Practical Deliverability	Flexibility	Independence	CONFIDENCE	Low impacts on habitat	Minimal increases in water losses	Low energy consumption	Low levels of flooding of urban areas	Low levels of flooding of agricultural land	Low levels of degradation of water quality	No disruption of water delivery other users	Low levels of disruption of recreation and tourism	Low levels of community resistance	Low levels of impact on built and cultural heritage	
C2S1	✔	✔	–	✔	✔	–	✔	✔	✔	✔	✔	✔	✕	–	–	Flexibility is reliant on carrier capacity.
C2S2	✔	✕	✔	✔	✔	✔	✕	–	✔	✔	✔	✔	✕	–	✔	Practical delivery is dependent on public participation.
C2S3	✔	✕	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✕	–	✔	Practical delivery is dependent on public willingness to sell.
C2S4	✔	✔	✕	✔	–	–	✔	–	✔	✔	✔	✔	✔	✔	–	Flexibility is reliant on carrier capacity.
C2S5	✔	✔	✕	✔	–	–	✕	–	✔	✔	✔	✔	✔	✕	–	Limited knowledge regarding a suitable site impacts on confidence.
C2S6	✔	✔	✔	✔	–	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	Limited knowledge on the operation of Greens Lake impacts on confidence
C2S7	✔	✔	✕	✔	–	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	Pulse size is dependent on required releases for irrigation. There is limited information to indicate that pulsing flows will have any environmental benefit.
C2W1	✔	✔	✕	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	
C2W2	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	
C2W3	✔	✔	✔	✔	–	–	–	✔	✔	✔	✔	✔	✔	–	–	The effectiveness and impact of pondage would depend site selection.
C3S1	✔	✔	–	✔	✔	–	✔	✔	✔	✔	✔	✔	✔	✔	–	Flexibility is reliant on carrier capacity.
C3S2	✔	✕	✔	✔	✔	✔	✕	–	✔	✔	✔	✔	✔	✔	✔	Practical delivery is reliant on third party participation. Pumping likely to be required. Evaporation losses from storages.
C3S3	✔	✕	✔	✔	–	✔	✔	✔	✔	✔	✔	✔	✔	–	✔	Knowledge gaps exist regarding the operation of the water market.
C3S4	✔	✔	✕	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	Flexibility is reliant on the availability of carrier capacity in adjacent systems.
C3W1	✔	✔	✕	✔	–	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	Knowledge gaps exist regarding the attenuation and timing of flow peak. Flooding is likely to trigger community resistance.
C4S1	✔	✔	✔	✔	✔	–	✔	✔	✔	✔	✔	✔	✔	✔	–	Flexibility is reliant on carrier capacity.
C4S2	✔	✕	✔	✔	✔	✔	✕	–	✔	✔	✔	✔	✔	✔	✔	Practical delivery is reliant on third party participation. Pumping likely to be required. Evaporation losses from storages.
C4S3	✔	✕	✔	✔	–	✔	✔	✔	✔	✔	✔	✔	✔	–	✔	Knowledge gaps exist regarding the operation of the water market.
C4W1	✔	✔	–	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	Flexibility is dependent on carrier capacity.
M1W1	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	

Selected Package

Selected Cost $ - million

Note: This table has been prepared as a part of preliminary option assessment only. Option impact and cost should be subject to detailed investigation before proceeding.

Option cost estimates are coarse and preliminary only and in particular do not include the cost of operation, maintenance, consultation, investigation, design and secondary impact mitigation

LEGEND	
2	Full compliance with environmental flow component
1	Partial compliance with environmental flow component
✔	Option complies with stated criteria
–	Option does not comply with stated criteria. Impact of non-compliance is short term/ localised.
✕	Option does not comply with stated criteria. Impact of non-compliance is long term/ widespread.

SKM

9.11.5 Birches and Tullaroop Systems Option Evaluation and Packages

- **Figure 10 Birches and Tullaroop System All Options**

All Options

		FLOW COMPONENTS													FEASIBILITY		ROBUSTNESS			SECONDARY IMPACTS										COMMENT
						Hepburn to Tullaroop																								
		SF	WL	WF	WH	SL	SF	WL	WF	WH	WB	EFFECTIVENESS	Constraint Cost ($ million)	EFFICIENCY	Technically Feasible	Practical Deliverability	Flexibility	Independence	CONFIDENCE	Low impacts on habitat	Minimal increases in water losses	Low energy consumption	Low levels of flooding of urban areas	Low levels of flooding of agricultural land	Low levels of degradation of water quality	No disruption of water delivery other users	Low levels of disruption of recreation and tourism values	Low levels of community resistance	Low levels of impact on built and cultural heritage	
	Weight	100	100	100	100	100	100	100	100	100	100																			
B1S1	Decommission Newlyn Reservoir	2	2	2	2	1	1	1	1	1	1	0.70	$3.00	0.23	✓	✓	✓	✓	✓	–	✓	✓	✓	✓	✓	–	–	–	✓	Loss of storage capacity may impact on water delivery to some urban centres.
B1S2	Increase Newlyn Reservoir outlet capacity at low storage levels to 10 ML/d	2	2	0	0	2	1	1	0	0	0	0.40	$0.50	0.80	✓	✓	✗	✓	✓	✓	✓	–	✓	✓	✓	✓	✓	✓	✓	Flexibility is limited by outlet capacity.
B1W1	Increase Newlyn Reservoir outlet capacity at low storage levels to 40 ML/d	2	2	2	0	2	2	2	1	0	0	0.65	$1.50	0.43	✓	✓	–	✓	✓	✓	✓	–	✓	✓	✓	✓	✓	✓	✓	Flexibility is limited by outlet capacity.
B1W2	Increase Newlyn Reservoir outlet capacity at low storage levels to 160 ML/d	2	2	2	2	2	2	2	2	1	0	0.85	$2.00	0.42	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	
B2S1	Decommission Hepburn Lagoon	0	0	0	0	2	1	1	1	1	1	0.35	$1.50	0.23	✓	✓	–	✓	✓	–	✓	✓	✓	✓	✓	–	–	–	✓	Loss of storage capacity will impede the capacity to control flows in the downstream reach.
B2S2	Increase Hepburn Lagoon outlet capacity at low levels to 10ML/d	0	0	0	0	2	1	1	0	0	0	0.20	$0.40	0.50	✓	✓	✗	✓	✓	✓	✓	–	✓	✓	✓	✓	✓	✓	✓	Flexibility is limited by outlet capacity.
B2S3	Increase Hepburn Lagoon outlet capacity at low storage levels to 27 ML/d	0	0	0	0	2	2	2	1	0	0	0.35	$0.70	0.50	✓	✓	✗	✓	✓	✓	✓	–	✓	✓	✓	✓	✓	✓	✓	Flexibility is limited by outlet capacity.
B2S4	Increase Newlyn Reservoir outlet capacity at low levels to 27 ML/d	2	2	1	0	2	2	2	1	0	0	0.60	$0.70	0.86	✓	✓	✗	✓	✓	✓	✓	–	✓	✓	✓	✓	✓	✓	✓	Flexibility is limited by outlet capacity.
B2W1	Increase Hepburn Lagoon outlet capacityat low storage levels to 275 ML/d	0	0	0	0	2	2	2	2	2	0	0.50	$3.00	0.17	✓	✓	–	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	Flexibility is limited by outlet capacity. Releases of this magnitude may reduce spills.
B2W2	Increase Newlyn Reservoir outlet capacity at low storage levels to 275 ML/d	2	2	2	2	2	2	2	2	2	0	0.90	$3.00	0.30	✓	✓	–	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	Flexibility is limited by outlet capacity. Releases of this magnitude may reduce spills.
B2W3	Increase Hepburn Lagoon outlet capacity to 1,300 ML/d	0	0	0	0	2	2	2	2	2	1	0.55	$6.00	0.09	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	Releases of this magnitude will mean that the reservoir is empty or partially full for an increased amount of time. This will reduce spills and could reduce security of supply.
B2W4	Increase Newlyn Reservoir outlet capacity to 1,300ML/d	2	2	2	2	2	2	2	2	2	1	0.95	$6.00	0.16	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	Releases of this magnitude will mean that the reservoir is empty or partially full for an increased amount of time. This will reduce spills and could reduce security of supply.
Selected Package																														
Selected Cost												million																		

Note: **This table has been prepared as a part of preliminary option assessment only. Option impact and cost should be subject to detailed investigation before proceeding.**

Option cost estimates are coarse and preliminary only and in particular do not include the cost of operation, maintenance, consultation, investigation, design and secondary impact mitigation

LEGEND	
2	Full compliance with environmental flow component
1	Partial compliance with environmental flow component
✓	Option complies with stated criteria
–	Option does not comply with stated criteria. Impact of non-compliance is short term/ localised.
✗	Option does not comply with stated criteria. Impact of non-compliance is long term/ widespread.

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9.11.6 Loddon System Option Evaluation and Packages

■ **Figure 11 Loddon System All Options (part one)**

All Options

FLOW COMPONENT

		Tullaroop Reservoir to Laanecoorie					Cairn Curran Reservoir to Laanecoorie Reservoir					Laanecoorie to Loddon Weir			Loddon Weir to Kerang			Kerang to River Murray		EFFECTIVENESS	Constraint Cost ($ million)	EFFICIENCY
		SL	SF	WF	WH	AH b	SCTF	SL	SF	WO	AH	SL	SF	WL	SL	WL	WO	SL	SF			
	Weight	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100			
T1S1	Decommission Tullaroop Reservoir	2	2	2	2	2	0	0	0	0	0	0	0	1	0	1	1	0	0	0.19		
T1S2	Pipeline or channel from Tullaroop to Laanecoorie	2	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.06	$60.00	0.00
T1S3	Winterfill storage at Fernihurst and on-farm storages for reach PDs	2	2	1	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0.08	$190.00	0.00
T1S4	On-farm and regional winterfill storages	2	2	1	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0.08	$1,000.00	0.00
T1S5	Pipeline from Tullaroop to Cairn Curran Reservoir	1	1	0	0	0	-2	-1	-1	0	0	0	0	0	0	0	0	0	0	-0.08	$106.00	0.00
T1S6	Augment capacity of WWC to supply Boort irrigators currently supplies from Tullaroop	1	1	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0.08	$260.00	0.00
T1S7	Enlarge capacity of Laanecoorie for winterfill from Tullaroop	1	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.03	$370.00	0.00
T1W1	Eliminate Tullaroop outlet vibration	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00	$0.50	0.00
T1A1	Increase Tullaroop outlet capacity to 3,000 ML/d	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0.06	$8.00	0.01
T1A2	Modify Tullaroop releases to piggyback on high tributary inflows	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00	$0.00	1.00
T1A3	Construct pondage downstream of Tullaroop	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0.06	$10.00	0.01
L1S1	Pipeline or channel from Cairn Curran to Laanecoorie including reach PDs	0	0	0	0	0	2	2	2	0	0	0	0	0	0	0	0	0	0	0.17	$36.00	0.00
L1S2	Supply from Tullaroop to Laanecoorie and provide on farm storages to reach PDs	-1	-1	0	0	0	2	-1	-1	0	0	0	0	0	0	0	0	0	0	-0.03	$13.00	0.00
L1S3	Pipeline from Cairn Curran to Tullaroop and provide on-farm storages to reach PDs	-1	-1	0	0	0	2	2	2	0	0	0	0	0	0	0	0	0	0	0.14	$150.00	0.00
L1S4	Augment capacity of WWC to supply Boort irrigators currently supplied from Cairn Curran	0	0	0	0	0	0	1	1	0	0	1	1	0	0	0	0	0	0	0.11	$300.00	0.00
L1S5	Enlarge capacity of Laanecoorie and winterfill from Cairn Curran	0	0	0	0	0	2	1	1	0	0	0	0	0	0	0	0	0	0	0.11	$500.00	0.00
L1S6	Winterfill storage near Loddon Weir at Fernihurst to cover cease to flow period (and provide on-farm storages to reach PDs	0	0	0	0	0	2	1	1	0	0	1	1	0	0	0	0	0	0	0.17	$400.00	0.00
L1S7	On-farm and regional winterfill storages to cover cease to flow period	0	0	0	0	0	2	1	1	0	0	1	1	0	0	0	0	0	0	0.17	$350.00	0.00

	FEASIBILITY		ROBUSTNESS			SECONDARY IMPACTS										COMMENT
	Technically Feasible	Practical Deliverability	Flexibility	Independence	CONFIDENCE	Low impacts on habitat	Minimal increases in water losses	Low energy consumption	Low levels of flooding of urban areas	Low levels of flooding of agricultural land	Low levels of degradation of water quality	No disruption of water delivery other users	Low levels of disruption of recreation and tourism	Low levels of community resistance	Low levels of impact on built and cultural heritage	
T1S1	✓	✓	✓	✓	✓	–	✓	✓	✓	✓	✓	–	–	–	✓	The decommissioning of a reservoir has the potential to cause loss of security of supply, recreational values and community resistance. Option was not costed given the complexity of the task.
T1S2	✓	✓	✓	✓	✓	–	✓	✓	✓	✓	✓	✓	✓	✓	–	Flexibility is limited by carrier capacity. Construction will disrupt habitat along the corridor.
T1S3	✓	–	✓	✓	✓	–	✗	✓	✓	✓	✓	✓	✓	–	–	Practical delivery requires participation from farmers. It is unclear what impact increased winterfill and on farm storages will have on overall catchment hydrology.
T1S4	✓	✗	✓	✓	✓	✓	✗	✓	✓	✓	✓	✓	✓	–	✓	Practical delivery requires participation from farmers. It is unclear what impact increased winterfill and on farm storages will have on overall catchment hydrology.
T1S5	✓	✓	✓	✓	✓	–	✓	✗	✓	✓	✓	✓	✓	✓	–	Flexibility is limited by carrier capacity.
T1S6	✓	✓	✗	✓	✓	–	✓	✓	✓	✓	✓	✓	✓	✓	–	Option is unable to deliver current environmental flow recommendations and is therefore unlikely to be able to deliver changed recommendations.
T1S7	✓	✓	✗	✓	✓	–	✓	✓	✓	✓	✓	✓	✓	–	–	Option is unable to deliver current environmental flow recommendations and is therefore unlikely to be able to deliver changed recommendations.
T1W1	✓	✓	✗	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	Flexibility is limited as option is only able to deliver one flow component.
T1A1	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	
T1A2	✓	✓	✗	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	Option is unable to deliver current environmental flow recommendations and is therefore unlikely to be able to deliver changed recommendations.
T1A3	✓	✓	✓	✓	✓	–	✓	✓	✓	✓	✓	✓	✓	–	–	Option is unable to deliver current environmental flow recommendations and is therefore unlikely to be able to deliver changed recommendations.
L1S1	✓	✓	–	✓	✓	–	✓	✓	✓	✓	✓	✓	✗	✓	–	Flexibility is limited by carrier capacity. Construction will disrupt habitat along the corridor. Impact on local recreational use of River.
L1S2	✓	–	–	✓	✓	✓	–	✓	✓	✓	✓	✓	✓	✓	✓	This option requires third party participation. In addition it will reduce the capacity of the system to supply summer lows and summer freshes.
L1S3	✓	–	–	✓	✓	–	✓	–	✓	✓	✓	✓	–	–	–	This option requires third party participation. In addition, it will reduce the capacity of the system to supply summer freshes between Tullaroop Reservoir and Laanecoorie.
L1S4	✓	✓	✗	✓	✓	–	✓	✓	✓	✓	✓	✓	✓	✓	–	Option is unable to deliver current environmental flow recommendations and is therefore unlikely to be able to deliver changed recommendations.
L1S5	✗	✗	✗	✓	✗	✗	✓	✓	✓	✓	✓	✓	–	✗	–	Option is unable to deliver current environmental flow recommendations and is therefore unlikely to be able to deliver changed recommendations.
L1S6	✓	–	✗	✓	✓	–	✗	–	✓	✓	✓	✓	✓	–	–	Option has limited flexibility and requires third party participation.
L1S7	✓	✗	✓	✓	✓	–	✗	–	✓	✓	✓	✓	✓	–	–	This option requires third party participation.

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▪ Figure 12 Loddon System All Options (part two)

L1S8	New winter-fill storage near Loddon Weir at Fernihurst to cater for irrigation supplies from Cairn Curran	0	0	0	0	0	2	2	2	0	0	1	1	0	0	0	0	0	0	0.22	$1,000.00	0.00	✓	–	✓	✓	✓	–	✗	–	✓	✓	✓	✓	✓	–	–	This option requires some level of third party participation,
L1S9	On farm and regional winterfill storages to cater for irrigation supplied from Cairn Curran	0	0	0	0	0	2	2	2	0	0	1	1	0	0	0	0	0	0	0.22	$1,000.00	0.00	✓	✗	✓	✓	✓	–	✗	–	✓	✓	✓	✓	✓	–	–	This option requires third party participation.
L1W1	Enlarge Cairn Curran outlet capacity to 3,000 ML/d	0	0	0	0	0	0	0	0	2	2	0	0	0	0	0	0	0	0	0.11	$8.00	0.01	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	Option is constrained by outlet capacity but could provide some range of flows.
L1W2	Construct pondage downstream of Cairn Curran	0	0	0	0	0	0	0	0	2	2	0	0	0	0	0	0	0	0	0.11	$6.00	0.02	✓	✓	✓	✓	✓	–	–	✓	✓	✓	✓	✓	✓	–	–	Flexibility is limited by the size of pondage. Impact depends on location of pondage. Some community resistance possible.
L2S1	Pipeline or channel from Laanecoorie to Loddon weir	0	0	0	0	0	0	0	0	0	0	2	2	0	0	0	0	0	0	0.11	$150.00	0.00	✓	✓	✗	✓	✓	–	✓	✓	✓	✓	✓	✓	–	✓	–	Flexibility is limited by carrier capacity. Construction will disrupt habitat along the corridor.
L2S2	Winterfill storage near Loddon Weir at Fernihurst and on-farms storages for all PDs	2	2	0	0	0	2	2	2	0	0	2	2	0	0	0	0	0	0	0.33	$1,200.00	0.00	✓	–	✓	✓	✓	–	✗	–	✓	✓	✓	✓	✓	–	–	Practical delivery requires some degree of participation from third parties.
L2S3	On-farm and regional winterfill storages	2	2	0	0	0	2	2	2	0	0	2	2	0	0	0	0	0	0	0.33	$1,000.00	0.00	✓	✗	✓	✓	✓	–	✗	–	✓	✓	✓	✓	✓	–	–	This option requires third party participation.
L2S4	Augment capacity of WWC to supply all Boort irrigators	1	1	0	0	0	0	1	1	0	0	1	1	0	0	0	0	0	0	0.14	$320.00	0.00	✓	✓	✗	✓	✓	–	✓	✓	✓	✓	✓	✓	✓	✓	–	This option is limited by carrier capacity. Inability to supply environmental flows via this mechanism mean that it is unlikely to be able to deliver changes flow recommendations.
L2W1	Increase regulatory capacity of Serpentine and Bridgewater Weirs	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0.06	$0.30	0.19	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	
L3S1	Flume gates on Loddon Weir to control low flows	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0.03	$0.00	1.00	✓	✓	✓	✗	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	Option is unable to deliver current environmental flow recommendations and is therefore unlikely to be able to deliver changed recommendations. This option relies on L3S2 and L3S3 being delivered at the same time.
L3S2	Improved management of sporadic diversions to ensure low flow requirements maintained	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0.03	$0.00	1.00	✓	✓	✗	✗	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	Option is unable to deliver current environmental flow recommendations and is therefore unlikely to be able to deliver changed recommendations. This option relies on L3S1 and L3S3 being delivered at the same time.
L3S3	Repair 12 Mile Creek Regulator	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0.03	$0.20	0.14	✓	✓	✓	✗	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	This option relies on L3S1 and L3S2 being implemented at the same time.
L3W1	Supply from WWC	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	2	0	0	0.11	$0.00	1.00	✓	✓	–	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	Flexibiilty is limited by carrier capacity.
L4S1	Pipeline or channel from Kerang Weir to Murray, plus Kerang Weir modifications to enable delivery of 7 to 12 ML/d	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	2	0.11	$90.00	0.00	✓	✓	✗	✓	✓	–	✓	✓	✓	✓	✓	✓	✓	✓	–	Flexibility is limited by carrier capacity.
L4S2	On-farm storages, plus Kerang Weir modifications to enable delivery of 7 to 12 ML/d	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	2	0.11	$4.00	0.03	✓	✗	✗	✓	✓	–	✗	–	✓	✓	–	✓	✓	✓	✓	Flexibility is limited by carrier capacity. Option requires some degree of third party participation. It is unknown what impact increased farm dams with have on groundwater.
Selected Package		**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**																			
Selected Cost								**$**								-				**million**																		

Note: **This table has been prepared as a part of preliminary option assessment only. Option impact and cost should be subject to detailed investigation before proceeding.**
Option cost estimates are coarse and preliminary only and in particular do not include the cost of operation, maintenance, consultation, investigation, design and secondary impact mitigation

LEGEND	
2	Full compliance with environmental flow component
1	Partial compliance with environmental flow component
✓	Option complies with stated criteria
–	Option does not comply with stated criteria. Impact of non-compliance is short term/ localised.
✗	Option does not comply with stated criteria. Impact of non-compliance is long term/ widespread.

10. Knowledge and Information Gaps

10.1 Knowledge Gaps

As is clear from previous chapters, this study has revealed a number of areas where improved information and knowledge would significantly enhance understanding of the measures required to enhance delivery of the recommended environmental flows, and increase the level of confidence that options will deliver the recommended flows.

There is relatively little information on the magnitude of transmission losses within many of the systems under consideration. This issue is particularly significant in long reaches where minimum summer flows are recommended and the streams in questions do not carry large summer irrigation flows. Particularly relevant examples are:

- Goulburn River downstream of Goulburn Weir;
- Coliban River between Malmsbury Reservoir and Lake Eppalock. This reach is known to experience high summer transmission losses (Bruce Duncan, Coliban Water, pers.comm.);
- Loddon River between Loddon Weir and Kerang Weir; and
- Birches and Tullaroop Creeks upstream of Tullaroop Reservoir.

The GSM water resources model of these systems does not include any transmission losses (seepage and evaporation) for either the Goulburn or Coliban Rivers for the reaches in question. Whilst the model includes a 1 ML/d groundwater inflow to the Loddon between Loddon Weir and Appin South and no transmission losses, and models transmission losses in Birches Creek as a percentage of inflow, there is significant uncertainty surrounding these estimates. In the absence of better information, it is difficult to predict the magnitude of flow that might need to be delivered into these reaches to produce the required environmental flow further downstream.

The middle reaches of the Loddon River between Serpentine Weir and Kerang Weir are characterised by a number of breakaway flow paths, only some of which return to the main River. Consequently the main channel of the Loddon is significantly smaller in this reach than in the adjacent reaches immediately upstream and downstream. This reach includes “The Chute” which was discussed in Chapter 7.2.

As in the case of transmission losses, there is relatively little available information on the magnitude of breakaway and return flows in this reach. This again means that it is difficult to estimate, with any certainty, the magnitude of flow that might need to be delivered into this reach to produce a required environmental flow at either Kerang Weir or the Murray confluence. This is particularly the case for moderate or high flows around bankfull level.

Whilst not investigated in detail as part of the study, there is also some uncertainty regarding the magnitude of attenuation of environmental flood releases that might occur downstream of storages. This is particularly relevant to Lake Eildon, Malmsbury Reservoir, and Cairn Curran Reservoir, where significant releases can be controlled via spillway gates or other similar outlet works.

There is also some uncertainty regarding the likely coincidence of downstream tributary inflows, which could be used to augment releases from storage to produce a required environmental flow. These factors make it difficult to estimate the magnitude of high flow releases from storages that would be required to produce a particular specified environmental flow further downstream. In the absence of further investigation, it is uncertain whether this is associated with a lack of gauging information, a lack of analysis of available flow information, or a combination of the two.

Relatively little information is available on flooding thresholds in many parts of the river systems under consideration, and the extent to which these might constrain delivery of high flow recommendations. This particularly applies to the Goulburn River around the township of Thornton (Guy Tierney, GBCMA, pers.comm.), Birches Creek, and Tullaroop Creek upstream of Tullaroop Reservoir.

10.1.1 Metering and Monitoring

Current regulated operation of the river systems is based on the provision of flows within a range governed largely by irrigation requirements and minimum flow provisions. Irrigation requirements generally follow crop demand patterns and do not vary significantly during peak season. Generally, regulated flows do not exceed irrigation demands, although limited provision for additional releases exist in the Goulburn and Loddon Bulk Entitlements. Overbank releases from gated storages are a consequence of achieving storage objectives rather than to meet environmental or downstream objectives.

The full implementation of environmental flows recommendations would require regulated flows outside the current standard operating range. The existing metering, monitoring infrastructure, organisational capabilities and decision support systems may be inadequate for operations to efficiently meet these recommendations.

Table 22 lists the hydrographic gauging stations in reaches where environmental flow recommendations have been made. In most cases these stations are located at the boundaries of the flow reaches, with fewer reaches having intermediate gauging sites. Exceptions to this include:

- Birches Creek, which has the most number of reaches without a hydrographic gauging station.
- Goulburn River from Molesworth to Seymour. There is only an intermediate gauging station at Trawool within this reach.

In addition to the hydrographic sites, other measurements are taken by authorities for operational purposes. These operational measurements will not be subject to the same quality checking as hydrographic data. Sites with measurement for operational purposes include:

- Releases from Newlyn Reservoir in the Birches Creek catchment;
- Regulated flows passing Campaspe Weir; and
- Flows passing through the weirs on Broken Creek.

At least one hydrographic station is located on the major tributaries of the rivers. In most cases the gauging station is located in the lower parts of the reaches. While this may provide a good assessment of the flows entering the main river their usefulness in forecasting river behaviour for environmental release decision making may be limited.

The hydrographic stations are part of the Flow Monitoring Partnership between the state government and statutory authorities. Thiess has the contract to maintain the hydrographic gauging stations and to provide hydrographic services. Thiess provided guidance on the adequacy of each site and known issues at each site, a summary of which is contained in Appendix C, Appendix D, Appendix E and Appendix F. Most sites are considered to provide an adequate measurement of flow.

It may be the case that hydrological models using rainfall and streamflow data and or the provision of additional streamflow monitoring stations may be required to provide tools to determine regulated releases to assist in meeting environmental flow objectives. Hydrological models do exist for many systems for Bureau of Meteorology flood forecasting purposes. These however are calibrated and focus on flood events and are unlikely to be suitable for general forecasting (pers comm. Bill Viney). The networks for flood forecasting may provide the additional detail required to allow development of models to support decision making.

Information on tributary flow patterns and behaviours will form an important input to storage operations to achieve environmental flow targets. In particular, sufficient knowledge of tributary behaviour will increase the ability to supplement tributary flows with regulated releases to meet overbank flow objectives. The existing sites alone are considered inadequate for this purpose, and additional metering and monitoring and/or improved sites would be required in managing and delivering environmental flows, particularly the larger flood flows that are required in spring and winter. The provision of additional sites will require detailed analysis of how they match in with existing systems and gauging networks, and how they will be used in decision making processes for environmental flow releases.

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■ **Table 22 Hydrographic gauging stations in reaches that have environmental flow recommendations**

Reach Number	Reach Description	Relevant Hydrographic Stations: Site ID	Site Name
Goulburn			
1	Lake Eildon to Molesworth	405203	Goulburn River @ Eildon
2	Molesworth to Seymour	405201	Goulburn River @ Trawool
3	Seymour to Nagambie	405202	Goulburn River @ Seymour
4	Nagambie to Loch Garry	405259	Goulburn River @ Goulburn Weir
		405200	Goulburn River @ Murchison
		405204	Goulburn River @ Shepparton
5	Loch Garry to the River Murray	405276	Goulburn River @ Loch Garry
		405232	Goulburn River @ McCoys Bridge
Living Murray contribution	Conformance assessed at Reach 5	405232	Goulburn River @ McCoys Bridge
Campaspe			
1	Coliban River: Malmsbury Reservoir to Lake Eppalock A – Lyal Road (main conformance point) B – Phillips Road (checking point U/S of A)	406215	Coliban River @ Lyal
2	Campaspe River: Lake Eppalock to Campaspe Weir A – Doakes Reserve (main conformance point) B – English's Bridge (checking point D/S of A)	406225	Campaspe River @ Lake Eppalock (Outlet Measuring Weir)
		406219	Campaspe River @ Lake Eppalock (Head gauge)
		406207	Campaspe River @ Eppalock
		406201	Campaspe River @ Barnadown
3	Campaspe River: Campaspe Weir to Campaspe Siphon	406203	Campaspe River @ Campaspe Weir
4	Campaspe River: Campaspe Siphon to the River Murray	406202	Campaspe River @ Rochester (Campaspe Siphon)
Living Murray contribution	Conformance assessed at Reach 4	406265	Campaspe River @ Echuca
Birches Creek			
1	Birches Creek: Newlyn Reservoir to Hepburn Race		
2	Birches Creek: Hepburn Race to Lawrence weir	407227	Birch Creek @ Smeaton
3	Birches Creek: Lawrence weir to Creswick Creek confluence		
4	Tullaroop Creek: Creswick Creek	407222	Tullaroop Creek @ Clunes

		Relevant Hydrographic Stations	
Reach Number	**Reach Description**	**Site ID**	**Site Name**
	confluence to Tullaroop Reservoir		
Loddon River			
1	Loddon River: Cairn Curran Reservoir to Laanecoorie Reservoir	407210	Loddon River @ Cairn Curran Reservoir
2	Tullaroop Creek: Tullaroop Reservoir to Laanecoorie Reservoir	407244	Tullaroop Creek @ Tullaroop Reservoir (Head Gauge)
		407248	Tullaroop Creek @ Tullaroop Res. (Outlet Meas. Weir)
3a	Loddon River: Laanecoorie Reservoir to Serpentine Weir	407203	Loddon River @ Laanecoorie
3b	Loddon River: Serpentine Weir to Loddon Weir	407224	Loddon River @ Loddon Weir
4	Loddon River: Loddon Weir to Kerang Weir	407205	Loddon River @ Appin South
5	Loddon River: Kerang Weir to the River Murray	407202	Loddon River @ Kerang
Living Murray contribution			

A number of potential sites (refer Table 23 below) have been suggested for further consideration for each system to aid in operation of the systems to better target releases and to fill in knowledge gaps.

Table 23 Potential Monitoring Sites

Site	Purpose	
	Operational	**Fill in knowledge Gap**
Goulburn System		
(a) New remote flow and level monitoring site at Molesworth to assist in regulated overbank flow operations.	Yes	Yes – will assist in determining flooding thresholds
(b) Remote monitoring of all existing sites including tributaries such as Acheron, Rubicon and Yea Rivers.	Yes – will assist in operation of Eildon outlet to piggyback flows	Yes – Assist in forecasting future flows
(c) Remote operation of Eildon Outlet	Yes - will assist in operation of Eildon outlet to piggyback flows	
(d) Flow and level monitoring sites, every 20 km along the entire reach of the river to assist in understanding flooding issues and losses.		Yes – Will assist in understanding flooding constraints and losses (transmission and operational)

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Site	Purpose	
	Operational	Fill in knowledge Gap
2)		
Broken Creek System		
(e) Remote monitoring of all existing sites.	Yes	Yes
(f) Monitoring of all diversion sites to prevent unauthorised diversion of low environmental flow releases	Yes – Control unauthorised diversion	
Campaspe System		
(g) Remote monitoring of all existing sites including Mt Pleasant Creek and Axe Creek.	Yes – will assist in operation of Malmsbury to piggyback flows	Yes – Assist in forecasting future flows
(h) Remote operation of Malmsbury spillway	Yes – will assist in operation of Malmsbury to piggyback flows	
(i) Flow and level monitoring sites, every 20 km along the entire reach of the river to assist in understanding flooding issues and losses.	Yes	Yes – Will assist in understanding flooding constraints and losses (transmission and operational)
Birches Creek System		
(j) Remote monitoring of flows downstream of Newlyn Reservoir and Hepburn Lagoon	Yes	Yes
(k) Monitoring of Lawrence weir.		Yes – Will assist in understanding flooding constraints and losses (transmission and operational)
3)	4)	5)
Loddon System		
(l) Remote monitoring of all existing sites below Cairn Curran and Tullaroop Reservoirs including Bet Bet Creek.	Yes – will assist in operation of Cairn Curran to piggyback flows	Yes
(m) Remote operation of Cairn Curran Reservoir spillway	Yes – will assist in operation of Cairn Curran to piggyback flows	
(n) Monitoring of all diversion sites between Loddon Weir and Kerang Weir to prevent unauthorised diversion of low environmental flow releases	Yes – Control unauthorised diversion	
(o) Flow and level monitoring sites, every 20 km along the entire reach of the river downstream of Tullaroop	Yes	Yes – Will assist in understanding flooding

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Site	Purpose	
	Operational	Fill in knowledge Gap
and Cairn Curran Reservoirs to assist in understanding flooding issues and losses.		constraints and losses (transmission and operational)
6)		

10.1.2 Environmental Flow Recommendations

Environmental flow recommendations typically specify minimum flow volumes, frequency and duration. For summer and winter minimum flows, an 'or natural' proviso is also often applied. In regulated rivers that have a high summer flow due to irrigation releases the intent of the summer low flow recommendation is to reduce the summer flow to a lower level. However, from a conformance point of view, if flow is greater than the recommended low flow volume it is assumed that conformance is achieved regardless of the degree to which the low flow volume is exceeded.

Summer low flow recommendations need to be specified more clearly either through the provision of a minimum **and** maximum summer low flow, or the provision of a mean or median summer low flow surrounded by a range of acceptable variation, eg ±20%. In either case a flow range is recommend within which the summer low flow can vary. An alternative is for the 'or natural' proviso to apply to the upper flow as well as the lower flow bound.

Typically, if the natural flow falls below the recommended minimum flow then the lower of the two (ie the natural flow) becomes the required flow for the period that it is below the minimum recommended flow. Likewise, if the natural flow is greater than the minimum flow recommendation then the natural flow can act as the upper bound or maximum summer low flow recommendation. If flow exceeds the upper bound then non-conformance would result. Clarification of the intent of Environmental Flow Technical Panels will be useful when progressing to more detailed feasibility studies.

Living Murray recommendations have been considered in the assessment of flow constraints. In some instances the Living Murray requirements are inconsistent with flow recommendations for Victorian tributaries. For example, Living Murray requirements during the summer period may exceed the summer low flow recommendation for the contributing streams.

While the analysis of constraints considered the ability to provide both tributary recommendations and Living Murray recommendations, more work is needed to better clarify and detail specific Living Murray contributions from tributary streams. Work is also needed to coordinate/integrate Living Murray contributions with tributary recommendations to maximise the environmental benefits to both tributary streams and the Murray and to avoid disbenefits to Victorian streams in order to provide Living Murray contributions.

10.2 Losses

The understanding of loss within irrigation systems has been driven by operational requirements, longer term resource planning, development of bulk entitlements and seasonal allocation assessments. In recent years studies to identify water savings have also led to further definition of loss, particularly in the gravity distribution systems.

The loss allowance for operational requirements is driven by the need to efficiently provide water to meet irrigation demands. The inclusion of losses in system planning is based largely on the understanding developed through current system behaviour and previous experience. In general, no formal methodologies have been developed for calculating losses under various flow regimes and catchment conditions. Longer term resource planning requires the development of loss estimates for inclusion in computer models (eg REALM) of the regulated systems. Loss assumptions within the models are aimed at providing representative estimates of loss for various scenarios.

The Goulburn Simulation Model is used as the basis for long term modelling of the Goulburn, Campaspe and Loddon Systems. The loss assumptions used in the model include:

- In the Goulburn River, transmission losses equal 5% of total Eildon outflow from Lake Eildon to Trawool. Groundwater losses equal 6% of the Eildon outflow from Trawool to Goulburn Weir. The loss in these reaches is limited to 500 ML/d.
- In the Campaspe River, transmission losses from Lake Eppalock to Campaspe Weir equal 4% of Eppalock releases. Operational losses at Campaspe Weir are 10% of the water supplied to irrigators and the WWC downstream of Campaspe Weir.
- In the Loddon River, river losses from Tullaroop Reservoir to Laanecoorie Weir and from Cairn Curran to Laanecoorie are 2% of flow. Operational losses at Loddon Weir are equal to flows supplied to the WWC from Loddon River up to a maximum of 260 ML/d.
- The Goulburn Simulation Model has no mechanisms to calculate and incorporate losses at Broken Creek.

Seasonal allocation assessments provide a conservative assessment of the water available to supply irrigation requirements. Loss calculations in seasonal allocations are discussed in detail in appendices C.3, D.2, E.3 and F.4. The basic assumptions are as follows:

- In the Goulburn River, a loss allowance equal to 8.7% of Lake Eildon release up to a maximum loss of 300 ML/d
- In the Birches Creek (Bullarook) system around 850 ML of loss for the season

- In the Loddon System the seasonal allowance for losses is around 17,800 ML
- Around 15,200 ML is allowed for losses in the Campaspe River
- In the Broken River 105 ML/d of losses in the river system are allowed for in the seasonal allocation assessment.

Loss calculations are written into the Loddon Bulk Entitlement Environmental Reserve Conversion Order in the estimation of natural flows. Other Bulk Entitlements do not include the calculation of losses.

The current state of knowledge regarding losses is generally inadequate for the operational planning of regulated releases to meet environmental flow recommendations. For delivery of a recommended flow over a longer period, losses could be determined based on knowledge gained in normal operations. For delivery of environmental flows over a shorter period such as freshes and overbank releases, additional work will be required to determine the necessary loss allowance.

10.3 Outfalls/Return Flows

Appendix N presents all outfalls for the irrigation areas determined in the Water Savings In Irrigation Distribution System study (SKM 2000). Some channel outfalls in the Murray Valley and Shepparton Irrigation Areas are used regularly to pass regulated supplies to the Broken Creek. The East Goulburn Main Channel with an outfall capacity of 250 ML/d is the main source of regulated supply to the Broken Creek. Most channel outfalls only pass excess flows due to either inefficient regulation of the system or rainfall rejections.

Unplanned outfall volumes are mainly dependent on the supply volumes in upstream channels. Expected outfall volumes can vary from 0 for smaller spur channels to thousands of megalitres at the end of larger channels such as the Number 6 system in the Central Goulburn area.

Currently Goulburn-Murray Water is implementing programs to improve measurement within the irrigation system including outfalls. These programs have resulted in (pers comm. Steve Shaddock G-MW):

- Rubicon's TCCS system being installed in the Central Goulburn 1 to 4 channels
- Installation of Rubicon Flumegates on the majority of outfalls in the Shepparton Irrigation Area
- A number of outfalls in the Murray Valley and Torrumbarry irrigation area having AWMA structures installed.

Further installation of improved measurement is planned for the remaining Central-Goulburn, Torrumbarry and Murray Valley Irrigation areas as well as Rochester and Pyramid-Hill Boort.

The improved measurement afforded by the increased and better measurement will provide a greater knowledge of actual outfalls and channel behaviour.

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11. Conclusions and Recommendations

11.1 Conformance with Environmental Flow Recommendations

Summer flows in the Goulburn River upstream of Goulburn Weir almost always significantly exceed the magnitude of flows required to provide for riffle habitat and shallow water habitat and are also typically below the minimum flow to provide for deep water habitat.

In all reaches of the Goulburn River, the frequency of overbank events is less than natural and less than recommended. However flow events of the magnitude required to fulfil Living Murray requirements are frequently experienced.

The Steering Committee has specified minimum flows for Broken Creek for the purpose of keeping fish ladders open, to minimise Azolla accumulation and to manage dissolved oxygen. These minimum flows occur in the majority of days during the specified months. Fresh flows for flushing Broken Creek in response to rapid Azolla blooms occur in nearly 90% of years, but it is not known whether fresh flows occur at the same time as Azolla blooms.

There is a significant flow inversion in the Campaspe downstream of Lake Eppalock, Loddon River between Cairn Curran Reservoir and Loddon Weir and downstream of Kerang Weir, and Tullaroop Creek downstream of Tullaroop Reservoir, with water being harvested in the winter months and released in the summer for irrigation supply. In most cases, river regulation has removed the natural flow variation from the system. Often the summer and winter fresh volumes are being met but the recommended number and duration are not.

11.2 Constraints to Delivery of Recommended Environmental Flow Regimes

The most significant constraint to the delivery of the recommended summer environmental flow regime in many of the systems is a need to deliver peak irrigation demands, in summer, via the streams in question. This applies to the Goulburn River between Eildon and Goulburn Weir, the Campaspe River downstream of Lake Eppalock, the Loddon River between Cairn Curran Reservoir and Loddon Weir, and downstream of Kerang Weir, and Tullaroop Creek downstream of Tullaroop Reservoir.

Delivery of recommended flows required for management of azolla in Broken Creek is predominantly constrained by a lack of available channel capacity to deliver these flows during the irrigation season.

Lack of available reservoir outlet capacity would constrain delivery of some of the recommended high flow components to the Coliban River downstream of Malmsbury Reservoir, the Campaspe

River downstream of Lake Eppalock, Birches and Tullaroop Creeks between Newlyn and Tullaroop Reservoirs, and Tullaroop Creek downstream of Tullaroop Reservoir.

Delivery of recommended high flows would also be constrained by the potential to exacerbate flooding along the upper Goulburn, particularly around Thornton and Molesworth, and along the Coliban River around Malmsbury.

11.3 Options to Deliver Flow Regimes

A range of options have been developed, where required, to improve the delivery of each recommended environmental flow component in each reach. The effectiveness of each of these options in delivering all environmental flow components across all reaches in the system to which the options apply has also been assessed. Each option has then also been assessed in terms of feasibility, robustness, confidence associated with its scoping and evaluation, and secondary impacts and consequences.

In reaches where delivery of the recommended summer flow regime is constrained by the need to deliver peak irrigation demands, the types of options that have been considered have generally comprised pipelines or channels to convey peak irrigation flows, on-farm or regional winter fill storages, supply of peak irrigation demands from other available sources, and pulsing of flows to provide some summer variability. In reaches where delivery of high flow components is constrained by lack of available reservoir outlet capacity, options considered have included modifications to outlet works, modified operation including piggybacking on high downstream tributary inflows, and construction of downstream pondages with high capacity outlet works.

The major outcomes of this study have been the development of a range of potential options to deliver the recommended environmental flow regimes, and demonstration of a process for:

- assessing the effectiveness of these options in delivering the recommended flows;
- packaging options to deliver multiple flow components in multiple reaches of each system; and
- assessing each option or packages of options in terms of feasibility, robustness, confidence associated with scoping and evaluation, and secondary impacts and consequences. Measures to reduce these secondary impacts have not been developed or costed.

Selection of options and packages of options for future implementation will depend on a large number of factors. Some of the more significant of these will include social impacts, availability of funding, availability of environmental water reserves, and political decisions about which systems and reaches should have the highest priorities for implementation of measures required to deliver the recommended flow regimes. It is also likely that the recommended environmental flow regimes will be refined over time, particularly in relation to the Living Murray Initiative.

More global factors such as climate and catchment change, and water trading, may also impact on option requirements and option assessment. Future refinement and selection of options and packages will need to take all these factors into account.

This study has developed and coarsely assessed a large number of options. Significant further investigations would be required for most options to confirm details, particularly estimated costs, and to provide more detailed assessment of their effectiveness and impacts.

11.4 Further Investigations and Monitoring

The study has revealed a number of areas where improved information and knowledge would significantly improve the understanding of measures required to enhance delivery of the recommended environmental flows, and the confidence that options will deliver the recommended flows. These include:

- Transmission losses, particularly in long reaches of river where minimum summer low flows have been recommended, and the reaches in question do not carry high summer irrigation flows;
- Magnitude of breakaway and return flows in the middle reaches of the Loddon River for flows around bankfull level;
- Magnitude of attenuation of flood releases downstream of some of the major storages; and
- Flooding thresholds that might constrain delivery of recommended high flows to some reaches.

Improved gauging and monitoring to address these knowledge and information gaps has been recommended.

The study has also indicated a number of areas where the recommended environmental flows require refinement or clarification, and other areas where some of the flow recommendations are inconsistent with each other.

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Appendix A Study Brief

Appendix B Steering Committee

Appendix C Operation of Goulburn System

Appendix D Operation of Broken Creek

Appendix E Operation of Campaspe System

Appendix F Operation of Loddon System

Appendix G Goulburn System Options

Appendix H Broken Creek Options

Appendix I Campaspe System Options

Appendix J Birches and Tullaroop Creek System Options

Appendix K Loddon System Options

Appendix L Flow Duration Curves

Appendix M Goulburn System Flood Frequency Analyses

Appendix N Irrigation Area Outfalls