Monitoring Environmental Flows in the Wimmera and Glenelg Rivers

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This is a report prepared for the Department of Sustainability and Environment, The Wimmera Catchment Management Authority and the Glenelg-Hopkins Catchment Management Authority

Executive summary

Diversions to the Wimmera-Mallee Stock and Domestic Supply System have substantially reduced the size and variability of flow in the Wimmera River since the 1840’s and in the Glenelg River since the 1950’s. The reduction of small to medium sized flows and freshes has reduced the quality and quantity of instream habitats, severed important connections between the river channel and its floodplain, and impaired important geomorphological processes. The most noticeable impacts include elevated salinity and reduced oxygen levels in deep permanent pools, reduced macroinvertebrate and native fish diversity and changes to the extent and diversity of instream and riparian vegetation.

Sinclair Knight Merz, the Victorian Department of Natural Resources and Environment, the CRC Freshwater Ecology, the Arthur Rhylah Institute and the Wimmera CMA conducted environmental flow studies and produced environmental flow recommendations for the Wimmera and Glenelg systems. Flow recommendations were developed through the FLOWS method, which identifies specific flow components (e.g. cease-to-flow periods, summer low flows, winter and spring freshes) that are needed to maintain, restore or improve ecological and geomorphological assets and processes. These environmental flow studies are described in detail in the Wimmera and Glenelg Stressed Rivers Reports and in the Wimmera Bulk Entitlement Conversion Report, and relevant aspects are summarised and discussed in this current report.

The Wimmera-Mallee Stock and Domestic Supply System is extremely complex. Flow can be diverted from or released into the Wimmera River and its tributaries at up to 10 release points and can be released into the Glenelg River at three points below Rocklands Reservoir. This means that current flows and future environmental flow releases can be controlled independently through a number of reaches. Environmental flow recommendations have been developed for each of these reaches. Small environmental flows have been released in some reaches of the Wimmera and Glenelg Rivers, but water savings from the Wimmera-Mallee Pipeline are expected to provide up to 83,000 ML/year for environmental flows through these systems. Environmental flow allocations will be steadily increased throughout the construction of the Wimmera-Mallee Pipeline, but even the full allocation of 83,000 ML/year will not be sufficient to deliver all flow components to every reach in the Wimmera and Glenelg systems. It is therefore expected that environmental flows will be variously allocated to different reaches throughout the system.

The main aim of this report is to provide the Wimmera and Glenelg-Hopkins CMAs with a monitoring program to assess the effect of environmental flow releases in the Wimmera and Glenelg catchments. This report outlines expected physical, chemical and ecological responses to the environmental flow releases and develops a monitoring program to test these hypotheses. Data collected from the monitoring program should help to determine whether the environmental flow releases are meeting specific environmental objectives and may provide information that will assist with the management and allocation of future environmental flows.

A substantial amount of environmental monitoring has already been done and continues to occur in the Wimmera and Glenelg systems. Water quality and flow data are routinely monitored at up to 59 sites throughout both catchments and the EPA conducts macroinvertebrate surveys at 80 sites every 3-7 years for its own research and for Victorian Index of Stream Condition monitoring. Research groups from Deakin University at Warrnambool and the Arthur Rylah Institute have monitored responses to experimental and already implemented environmental flow releases. Data from these programs provide a useful baseline and may highlight some changes associated with environmental flow releases, but a dedicated monitoring program is required to demonstrate specific responses to future environmental flows.

The monitoring program design should causally link observed environmental responses with the delivery of environmental flows. Fully replicated studies that compare changes at control and impact locations before and after environmental flows commence provide the strongest inference, but various factors constrain such designs in large river systems and other approaches are often needed to demonstrate responses to particular management actions.

The standard Before-After-Control-Impact (BACI) design is difficult to apply in either the Wimmera or Glenelg systems for two reasons. First, there are no comparable control rivers that are similarly regulated but won’t receive environmental flows. Second, environmental flows have already started and will be gradually increased as the different stages of the pipeline are completed, ruling out a simple before-after comparison. Our recommended design focuses on temporal trends at key sites within each reach. These sites are selected based on their representativeness for a given reach, their access, availability of existing data for chosen indicators, and presence of pools (an important habitat for environmental flow objectives). We suggest that the sites used by SKM in deriving the environmental flow objectives should be the highest priority.

Some contrasts between reaches will also be informative, e.g. comparing upstream and downstream of Glenorchy on the Wimmera, where upstream acts as a reference reach and will indicate natural fluctuations through time. Some before versus after contrasts are also possible, e.g. comparing changes in reaches such as the MacKenzie River and Burnt Creek below Toolondo Channel that currently have almost no water due to diversions but will have closer to natural flows once environmental allocations are made.

We recommend a range of physical and biological variables that will indicate both short and longer term responses to environmental flows. Observations at each site under environmental flow releases will be required to show that the flows are producing the predicted hydrological and hydraulic responses e.g. inundated banks or connected pools. Water quality parameters, especially salinity (i.e. conductivity) and dissolved oxygen (DO) in pools over summer, are particularly important since poor water quality in pools has been identified as a limiting factor for native aquatic biota. Macroinvertebrates are problematical to monitor as their links to flow changes are not clear and they show great variability at a range of spatial and temporal scales requiring intensive sampling. We do not recommend including macroinvertebrates beyond regular Index of Stream Condition monitoring. Fish are potentially important indicators and should be sampled during late spring or early summer. Fish recruitment is an important indicator and so fish sampling should include a measure of relative juvenile abundance.

Data on water quality collected over the first 12 months should be analysed to assess spatial and temporal variability. Preliminary power and cost-benefit analyses would allow the sampling design to be optimised as required.

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1. Introduction

The Wimmera River is Victoria's largest endoreic river (i.e. doesn't flow to the sea) with a catchment area of 2,401,130 ha. It flows northwest from Mount Buangor State Park to Lake Hindmarsh and other terminal lakes in Wyperfeld National Park. Mt William Creek and MacKenzie River contribute flow from the Northern Grampians, while Yarriambiack Creek is the main distributary and flows north towards and through Warracknabeal.

Northwestern Victoria has a semi-arid climate and rainfall varies seasonally (winter/spring peak) and spatially (decrease from south to north) throughout the Wimmera catchment (EPA 1998). Rainfall over the Grampians and Pyrenees is generally between 700 and 1000 mm/year, but decreases to around 550 mm/year over the southern plains and 300 mm/year over the northern plains. A significant proportion of rainfall in the Grampians and Pyrenees becomes run-off. Winter rainfall on the southern plains enters the Wimmera River as run-off, but evaporation generally exceeds rainfall in the northern part of the catchment.

Since European colonisation the natural flow regime of the river has been substantially altered. Water diversions for the Wimmera-Mallee Stock and Domestic Supply (WMDS) system has resulted in significant changes to the magnitude, timing and duration of flows. In particular, there have been dramatic reductions in both the natural variation of discharge and the total magnitude of flows (SKM 2001).

In response to changes in land use and flow regime, there has been a marked deterioration in water quality within the Wimmera River. Saline groundwater intrusions have increased in the lowland reaches of the river and this has partly contributed to an overall increase in surface water salinity (SKM 2001). Water quality issues related to nutrient levels and dissolved oxygen concentrations are also of concern. The combination of changed hydrology and poor water quality are likely to have had significant direct and indirect effects on in-stream and riparian biota within the Wimmera River.

The Glenelg River rises in the Grampians and flows to the Southern Ocean. The catchment is approximately 120 km wide and 100 km from north to south, covering a total area of 1,266,030 ha (DWR 1989). Rainfall varies seasonally and spatially within the catchment. Winter is the wettest season and there is a gradual decline in mean annual rainfall from the coast near Nelson (approx. 750 mm) to the centre of the catchment (approx. 550 mm).

Rocklands Reservoir diverts a substantial proportion of flow from the upper catchment to the Wimmera-Mallee Stock and Domestic Supply System. Upstream of the reservoir, streamflows (frequency, duration and magnitude) are similar to natural conditions for the majority of the year. However, downstream of Rocklands Reservoir, streamflows are significantly altered from natural.

Below the reservoir flow seasonality has been reversed (SKM 2001). Current flows are less than natural flows during all months, and zero flows occur between May and November.

Water extraction and flow regulation have had a dramatic effect on the ecology of Australia's rivers (Walker, 1985). Flow changes in the Wimmera and Glenelg systems have among other things contributed to degraded water quality, reduced quality and quantity of aquatic habitats, reduced nutrient cycling and a loss in abundance and diversity of native instream and riparian biota.

The construction of the Wimmera-Mallee Pipeline will improve the efficiency of the Wimmera-Mallee Stock and Domestic Supply and the majority of water savings are to be returned to the rivers as environmental flows. Initial stages of the Northern Mallee Pipeline have already contributed small amounts of water (initially 7000 ML in 1993/94) for environmental flows in both the Wimmera and Glenelg Rivers, but this will increase up to 83,000 ML/yr when the Wimmera-Mallee Pipeline is complete. The allocation for 2002/03 was 36,690 ML, but drought conditions prevented this allocation from being delivered.

A scientifically rigorous and defensible monitoring program is required to assess ecological responses to these environmental flows. Results from both short and long-term monitoring will enable us to determine the benefits of implemented flow releases and then modify water management plans to better suit the needs of the environment, but we caution against using short term monitoring results as a sole basis for modifying management plans. This approach will provide a means of justifying water allocations for environmental purposes.

1.1 Project Scope

Environmental assets, issues, restoration objectives and environmental flow rules have been developed for the Wimmera and Glenelg Rivers through the Stressed Rivers Project (SKM, 2002a; b) and the Wimmera Bulk Entitlement Conversion (SKM, 2003a). The current project reviews these reports and other information to develop a conceptual model for the Wimmera and Glenelg Rivers and identify environmental restoration targets for these systems.

The main aim of this project is to develop a scientifically rigorous monitoring program that assesses the effect of environmental flow releases and tests whether implemented flows achieve the desired objectives.

The first stage of this project is the development of a conceptual model that describes the environmental condition and assets of the Wimmera and Glenelg systems and predicts ecological responses to environmental flow releases in those systems. We review existing biological, physical, hydrological and water quality data from these catchments, determine the spatial scale and extent of this data and identify specific knowledge gaps. This review has been used to help select response variables and study sites that can be used in the monitoring program.

An important step in designing a monitoring program is to determine the availability of potential control or reference sites and consider the spatial distribution of these and test sites. The unique nature of the Wimmera and Glenelg Rivers and the operation of the Wimmera Stock and Domestic System mean that there are few potential control and reference sites for assessing the effect of environmental flow releases in the Wimmera and Glenelg Rivers. As a result, the proposed monitoring program uses a multiple lines of evidence approach and temporal trends to determine whether the implemented environmental flows satisfy the prescribed ecological targets and objectives. Monitoring sites to be used in the program are selected based on the availability of existing data at specific locations and the expected spatial variation of selected variables.

The final chapter of this report outlines a monitoring program for the Wimmera and Glenelg Rivers that includes a list of specific study sites, a description of response variables including appropriate sampling methods and sampling frequency and recommendations for data collation, analysis and interpretation.

1.2 How to use this report

The conceptual model and environmental flow objectives for the Wimmera and Glenelg River Systems are based on The Stressed Rivers (SKM, 2002a; b) and Bulk Entitlement Reports (SKM, 2003a) for the Wimmera and Glenelg Rivers. The current document is intended to be a stand-alone report and therefore the preliminary chapters summarise information from previous SKM reports and put it into context for a conceptual model for the Wimmera and Glenelg Systems. Readers who are already familiar with the Stressed Rivers and Bulk Entitlement Reports and the proposed Wimmera Mallee Pipeline project may go straight to chapters 6 and 7 for a review of existing data and a description of the proposed environmental flows monitoring program.

2. Catchment descriptions

2.1 Wimmera:

Much of the Wimmera River basin, particularly the lowland northern reaches, is semi-arid. Under natural (or pre-water resource development) conditions, the Wimmera River had highly variable flow with intermittent flow in the lower reaches (Anderson, Morrison, 1989d). Progressive agricultural development of land in the Wimmera River catchment for cropping and pasture has increased demand for irrigation, stock and domestic water. As a result the river has been regulated since the 1840's to its current level of development which includes the Wimmera-Mallee Stock and Domestic Supply (WMSDS) and licensed private extractions.

The WMSDS consists of 12 storages and 18,000 km of earthen channels (Western, 1994) that divert water from the Wimmera River and its tributaries, as well as the Wannon, Glenelg, Murray and Goulburn river catchments (Overman, 1996). Water also enters the system through runoff from small streams and directly into the channels (SKM, 2001).

System operation in the Wimmera River catchment is extremely complex (SKM, 2001) and flow regimes vary considerably between reaches. Major diversions from the Wimmera River occur at Glenorchy Weir and Huddleston Weir. Water is diverted from Glenorchy Weir directly into the distribution system, while at Huddleston Weir water is diverted into off-stream storages at Pine and Taylors Lakes (DCNR, 1994). The WMSDS has the capacity to divert all flows up to 1600 ML/d from the Wimmera River at Huddleston Weir and approximately 54,000 ML/year is diverted from the Wimmera River at this point (Martin, Leeson, 2000).

Other main storages and structures include Lake Lonsdale, Lake Wartook and Distribution Heads. Lake Lonsdale is an off-stream storage on Mt William Creek. It has a capacity of 65,500 ML and receives flow from Lake Bellfield and Fyans Lake. It is a shallow Lake and is only used when other storages are full. Releases and flood spills from Lake Lonsdale flow into Mt William Creek and then to Glenorchy Weir pool via the Main Central Inlet Channel. Lake Wartook captures flow at the headwaters of the MacKenzie River and has a capacity of 29,360 ML. Controlled releases from Lake Wartook enter MacKenzie River and then Mt Zero Channel to supply Horsham. In most years 5-7 ML/day passes the Mt Zero Channel offtake and travels to Pine and Taylors Lakes via Distribution Heads. Distribution Heads is a modified wetland with a capacity of 100 ML, that harvests all water in the MacKenzie River as well as interbasin transfers from Rocklands Reservoir. Distribution Heads outflows to the MacKenzie River, Burnt Creek and the Old Natimuk Channel. Burnt Creek transfers flow to Pine and Taylors Lakes via the Toolondo Channel. Flow from the MacKenzie River and Burnt Creek only reach the Wimmera River during wet conditions.

Diversions from Glenorchy and Huddleston Weirs account for 48% of the total average annual yield of the Wimmera River catchment. The remaining 52% flows down the river (Hooke, 1991), but flow is highly variable and therefore the actual proportion of flow that is harvested varies between years. Water is also released into the weir pool at Glenorchy from the eastern storages (Lakes Bellfield, Lonsdale and Fyans) for passage downstream and to fill diversion channels to the north (J Martin, *pers. comm.*).

Commercial, domestic and stock, irrigation and communal supply licences divert 1465 ML/year from the Wimmera River downstream of Huddleston Weir, but there is no direct instream flow management in the Wimmera River downstream of MacKenzie River (SKM, 2002a). Domestic and stock (2.2ML/year), and commercial licences are used uniformly throughout the year, while irrigation licences permit extraction between October and March with a peak in January. Licensed extractions are greatest downstream of Horsham, with irrigators being the highest users. The WMSDS, water extraction and licence arrangements are further discussed in SKM 2001.

Regulation in the Wimmera River has substantially altered the natural flow regime (see Anderson and Morison 1989a). Gauged flows in the Wimmera River upstream of Glenorchy are not significantly different to the modelled natural flows (SKM, 2001), but flows between Glenorchy and Huddleston Weir are higher than natural and flows downstream of Huddleston Weir are much lower than natural (SKM, 2001). Under current development conditions there is no flow over Huddleston Weir for approximately 95% of the time between February and March. Flow diversion at Huddleston Weir means the immediate downstream reach receives no flow for significant periods and reaches further downstream have artificially prolonged low and intermittent flow.

Glenorchy and Huddleston Weirs and other WMSDS structures mitigate most small to moderate flow events. As a result, the Wimmera River downstream of Huddleston Weir has lost its low to medium flushing flow regime but is still subject to major floods.

Alterations to the natural flow regime are likely to have implications for water quality, geomorphological processes and direct and indirect effects on instream and riparian biota in various reaches of the Wimmera River.

The primary flow-related water quality issues in the Wimmera River are high salt and nutrient levels and low dissolved oxygen (Anderson, Morrison, 1989c). Land clearing has increased salt loads in the Wimmera River, but reduced flow volumes, frequency and duration exacerbate this problem by restricting mixing between saline and fresh water and contributing to stratified, hypoxic conditions especially in pools. High salinity may directly affect survivorship and growth of aquatic biota and also reduce the quality and quantity of available habitats (Mitchell, *et al.*, 1996). High nutrient loads enter the Wimmera River with sediment during high flow events and accumulates in the lower catchment (Craigie, *et al.*, 1999). Nutrients are released from these sediments under anoxic conditions that occur during low flow. High nutrient levels in the Wimmera River are associated with filamentous algal blooms, excessive macrophyte growth and reduced habitat quality through eutrophication, reduced oxygen concentration, channel restriction and sedimentation (Anderson, Morrison, 1989a; Craigie, *et al.*, 1999). Deoxygenation occurs at low flow in all waters deeper than 2 m downstream of Huddleston Weir (Anderson, Morrison, 1989e). This reduces the quality and quantity of aquatic habitats in a similar manner to high salt loads.

Vegetation clearing within the Wimmera catchment has resulted in sheet and bank erosion, bed incision of tributary streams and sediment delivery to the Wimmera River. Reduced flows contribute to sediment accumulation in the lower sections of the Wimmera River (Craigie, *et al.*, 1999). Accumulated sediments smother important habitat elements and fill pools, which reduces the quality, quantity and diversity of habitats for instream biota.

Low or zero flows may lead to significant loss of fish and macroinvertebrate habitat. Temporary habitat losses would occur naturally in the Wimmera River, but regulation has exacerbated the frequency and duration of these events downstream of Huddleston Weir (Anderson, Morrison, 1989a). Shallow riffle and run habitats are lost as flows decrease; these habitats represent 30 % of the channel length in the Wimmera River and are considered important habitat for fish and macroinvertebrates (Anderson, Morrison, 1989d). Runs support aquatic macrophyte growth and therefore increase habitat complexity. In addition, runs maintain connectivity between pools, which in turn provide refugia for aquatic fauna during periods of low flow.

The loss of small to medium flow events downstream of Huddleston Weir may also impact upon the life history processes of a number of the endemic fish and macroinvertebrate species that occur in the study area. Doeg (2000) suggests that while Australian Smelt, Southern Pygmy Perch and Mountain Galaxias breed largely independent of flooding in other parts of Victoria, the onset of higher flows (and subsequent improved water quality) and the timing of breeding may coincide in the Wimmera River region. Flat-headed Gudgeon also had an extended breeding season following the release of environmental flows in the McKenzie and Wimmera Rivers (Zampatti *et al* 1997).

The fauna and flora of the terminal lakes in the Wimmera River system are also likely to have been affected by the altered frequency, magnitude and duration of flows to the lakes (Overman, 1996). The average return period for flows beyond Lake Albacutya has been altered from 1 in 20 years under natural conditions to 1 in 100 years under regulated conditions. Reduced flood frequency is thought to be responsible for tree dieback in the lower Wimmera region (Overman, 1996). Anderson and Morison (Anderson, Morrison, 1989b) suggested that environmental water allocations in the order of 20,000 ML would need to be released during periods of high flow to restore, as far as possible, essential parts of the natural hydrology and ensure the long term survival of ecosystems dependant on the Wimmera River.

2.2 Glenelg:

The Glenelg River rises in the Victoria and Serra Ranges in the Grampians and flows to the Southern Ocean at Nelson. The Wannon River also originates in the Grampians, but flows southeast then west until it joins the Glenelg River near Casterton. The catchment covers approximately 1,266,030 ha (DWR, 1989) and its topography varies from rugged escarpments in the north-east to coastal plains in the south-west. The central portion of the catchment is composed of the deeply dissected Dundas and Merino tablelands that drop to flat basalt plains near Hamilton. The Glenelg estuary is over 70 km long and is one of the State's longest (Sherwood, *et al.*, 1998).

Rainfall varies seasonally and spatially throughout the catchment. Winter is the wettest season; mean annual rainfall gradually decreases from around 750 mm near the coast to approximately 550 mm in the middle of the catchment, but then rises to over 900 mm in the Grampians (DWR, 1989). Streamflow patterns reflect this variation with 70% of average annual flow in the Glenelg River upstream of Wannon River occurring between August and October. Under natural conditions the Glenelg River at Balmoral would cease-to-flow between February and April and sometimes longer (Godoy, 1996), but cease-to-flow periods do not occur within the current flow regime.

The Glenelg catchment has three main storages. Konong Wootong Reservoir is a small storage on Den Hills Creek, which is a tributary of the Wannon River. This reservoir has a capacity of 1,920 ML and diverts approximately 852 ML/year from the system to supply Casterton and Coleraine townships (Ingeme, 1996). Moora Moora Reservoir is a small, offstream storage in the upper reaches of the Glenelg with a capacity of 6,300 ML. Rocklands Reservoir is the largest storage in the catchment with a capacity of 348,000 ML and has the greatest impact on flow in the Glenelg River. Rocklands Reservoir diverts flow to Toolondo Reservoir in the Wimmera catchment to support the WMSDS system. Other flow impacts in the catchment include flow diversions from the First and Second Wannon Creeks to Lake Bellfield in the Wimmera Catchment and licensed extractions from the main river channel and tributaries. Irrigation, stock and domestic licences can extract up to 950 ML/year from the Glenelg catchment, but only 68.2 ML/year is extracted directly from the main channel of the Glenelg River and all of this is upstream of the Wannon River confluence (J. Donovan, pers. comm.).

Rocklands Reservoir has reduced mean annual flow downstream of the dam from 113,000 ML to 42,700 ML (SKM, 2003c). The Reservoir significantly affects seasonal flow patterns in the reach immediately downstream, but the overall impact decreases with distance from the dam as unregulated tributaries join the Glenelg River. Rocklands has a storage capacity about three times its average annual inflow and spills about once every four years. Controlled flows from Rocklands Reservoir generally enter the Glenelg River at Five-Mile and Twelve-Mile outfalls and therefore bypass Frasers Swamp. Compensation flows from Rocklands Reservoir to the Glenelg River are currently set at 3,300 ML/year and are intended to maintain target flows of 5-10 ML/day at Fulham Bridge and 1-2 ML/day at Harrow during summer and autumn. Compensation flows generally commence in November to take advantage of the wet river channel and therefore prevent flow from ceasing altogether (Godoy, 1996).

Unregulated tributaries contribute natural flow to the Glenelg River and flow downstream of Chetwynd River is normally continuous. However, in December 2000, the Glenelg River ceased flowing below Casterton (M. Tranter pers. comm.). Current releases from Rocklands Reservoir do not appear to exert an influence below Casterton due to the limited availability of water for release (Mitchell, *et al.*, 1996). Rather, streamflow at Casterton is influenced by inflow from other sources including tributaries and local rainfall.

Flow regulation, salinity and sedimentation are the main issues affecting the condition of the Glenelg River, but the relative importance of these issues varies between individual reaches (SKM report?).

Salinity varies along the Glenelg River and depends on the structure of the channel and groundwater intrusions. Saline groundwater intrusions are the major source of salt in the Glenelg River (GRCLPB, 1997). At low flow, salt concentrations are high, but fresh surface waters dilute or mask salinity at high flow (Sherwood, *et al.*, 1998). Salinity increases with downstream distance between Rocklands Reservoir and Fulham Bridge (Sherwood, *et al.*, 1998) and also varies between surface and bottom layers in this reach (McGuckin, *et al.*, 1991). Salt is less of an issue downstream of Casterton (McGuckin, *et al.*, 1991) where the flow regime is more natural.

Deoxygenation is also a problem throughout the Glenelg River and is closely associated with the presence of saline pools between Rocklands Reservoir and Fulham Bridge (McGuckin, *et al.*, 1991). Elevated salt concentrations and deoxygenation, particularly in deep pools, reduces the quality and quantity of habitats and refugia for aquatic biota.

Extensive land clearing and the introduction of rabbits have lead to significant erosion throughout the Glenelg catchment and this delivers high sediment loads to the Glenelg River and its tributaries. The reduced magnitude, frequency and duration of medium to high flows means that this sediment is not flushed out of the system and it infills important pool habitats and smothers coarse substrates, woody debris and macrophytes. These changes decrease the availability and diversity of important habitats, spawning sites and food sources for native fish and macroinvertebrates. Low flow and sand deposition have promoted excessive *Typha spp.* and *Phragmites australis* growth in the middle and upper reaches of the Glenelg River, which further impedes flow and increases sediment deposition (Mitchell, *et al.*, 1996). Sediment impacts have reduced channel capacity by 60% between Harrow and Burke’s Bridge, by 20% between Chetwynd River and Wannon River and by 10% downstream of the Wannon River confluence (Rutherfurd, Budahazy, 1996).

3. Wimmera-Mallee Pipeline

The Wimmera Mallee Stock and Domestic Supply System comprises 18,000 km of open, earthen channels that deliver water to 22,000 farm dams and 51 towns across three million hectares. The system is the largest of its kind in the world, but is very inefficient. A review of operations data from 1994 to 1999 indicated that on average 120,000 ML/year were released from the Grampians storages to meet end use demands of only 17,500 ML/year (Wimmera Mallee Water, 2002). Transmission and seepage losses from the earthen channels account for about 85,000 ML/year and evaporation and seepage from farm dams account for nearly 18,000 ML/year (Wimmera Mallee Water, 2002).

The proposed Wimmera Mallee Pipeline will replace the earthen channels with 6,500 km of pipes and will recommend that farm dams be lined and/or covered. The pipeline will be designed to deliver 27,000 ML/year for current and future demand within the supply area, and will improve the quality and efficiency of that supply (Wimmera Mallee Water, 2002). When complete the Wimmera Mallee Pipeline will deliver water savings of up to 93,000 ML/year. Up to 83,000 ML/year will be returned to the Wimmera, Glenelg and other rivers in the region as environmental flows and 10,000 ML/year will be used for new development outside the pipeline system (Wimmera Mallee Water, 2002).

Environmental flow releases can be made from Rocklands Reservoir and up to 10 locations throughout the Wimmera system. The main release points for the Wimmera River are Glenorchy Weir and the Lake Taylor Outlet Channel. At present, high flows can pass Huddleston Weir and the Wimmera Inlet Channel can be blocked to force spilling flows down the Wimmera River, but Huddleston Weir itself will need to be modified if a wider range of environmental flows are to pass this point. Flow from regulated tributaries such as Burnt Creek and MacKenzie River have the potential to influence flow in the Wimmera River downstream of Horsham. Potential flow release points on Wimmera River tributaries include the Mt Zero Channel, Distribution Heads and Toolondo Channel on the MacKenzie River and Burnt Creek and the Lake Lonsdale outlet and Main Central Outlet Channel on Mt William Creek.

Transmission losses and tributary inputs reduce the magnitude and effect of environmental flow releases downstream of release points. Flows up to 1000 ML/day can be released from Rocklands Reservoir (500–600 ML/day from the wall and 400-500 ML/day from five mile and twelve mile outlets) (Mitchell, *et al.*, 1996). Large releases could potentially affect flow in the Glenelg River down to Dartmoor, but smaller sustaining flows will have little effect downstream of Casterton. For example, releases of 36 ML/day from the 12 mile outlet provide flows of 10 ML/day at Harrow and 5 ML/day at Bouke’s Bridge, but are not likely to have an effect further downstream (Mitchell, *et al.*, 1996). Different transmission loss rates have been reported for various reaches in the

Wimmera River. Anderson and Morison (Anderson, Morrison, 1989e) estimated stable flow transmission losses of 35% in the Wimmera River between Horsham and Dimboola, 19% between Locheil and Tarranyurk, and more than 20% between Tarranyurk and Jeparit. These estimates were based on released flows of 50-60 ML/day. Transmission losses through these reaches after cease-to-flow periods and for smaller flows less are substantially higher (Anderson, Morrison, 1989e). There are no environmental flow release points in the Wimmera River downstream of the MacKenzie River confluence and therefore environmental flows are expected to have a diminished effect in the lower Wimmera River. Large environmental flow releases may provide some flow downstream of Lochiel, but controlled releases are not expected to affect flow to Lake Hindmarsh and Lake Albacutya.

It is intended that environmental releases will follow prescribed flow rules where possible, but allocations may vary from year to year. The Pipeline will be built over several years and environmental flows will be gradually returned to the rivers over this time. Current savings from the Northern Mallee Pipeline were supposed to deliver 35,000 ML of environmental flows by July 2002, but drought conditions have prevented this full allocation.

4. Environmental Objectives and Ecological Targets

4.1 Broad catchment objectives

The Stressed Rivers Project (SKM, 2002a; b) determined environmental objectives for the Wimmera and Glenelg Rivers. These objectives are summarised below and form the basis for environmental flow recommendations in each river.

4.1.1 Wimmera River Catchment

Six broad objectives have been determined for the Wimmera catchment:

1) Provide an environmental flow regime throughout the year that includes:
    - periods of no flow comparable in frequency and duration to those that would have occurred during pre-water resource development conditions;
    - minimum environmental flows during low flow periods; and
    - flows of a sufficient magnitude to maintain water quality and facilitate geomorphological processes.
2) Maintain, and where possible restore, longitudinal connectivity by:
    - providing minimum environmental flows during low flow periods;
    - ensuring farm dam development in the upper catchment does not impact upon flow magnitude and variability in downstream reaches; and
    - improving the frequency, duration and magnitude of floods in the terminal lakes.
3) Maintain, and where possible improve, stream habitat condition by providing environmental flows that can facilitate channel forming processes.
4) Manage flows for 24 threatened, flow dependent flora species.
5) Maintain self-sustaining populations of endemic native fish including River Blackfish, Southern Pygmy Perch and Mountain Galaxias.
6) Manage flows to minimise algal blooms and the development of Azolla mats.

4.1.2 Glenelg River Catchment

Six broad objectives have been determined for the Glenelg catchment:

1) Provide an adequate environmental flow regime throughout the year that includes:
    - Periods of no flow but without extending their frequency or duration;
    - Minimum environmental flows during low flow periods;

- Appropriate flushing flows to manage salinity and nutrient levels; and
- Large channel forming flows.

2) Maintain and restore longitudinal connectivity by:
    - Ensuring farm dam development in the upper catchment does not impact flow levels and variability in downstream reaches; and
    - Improving flow over/through existing weirs.

3) Maintain and improve (where possible) stream habitat condition to enhance:
    - channel morphology (including large woody debris);
    - riparian vegetation; and
    - instream vegetation.

4) Maintain and enhance self-sustaining populations of endemic native fish with particular emphasis on threatened species.

5) Manage flows for 24 threatened, flow dependent flora species.

6) Ensure that links to other strategies are fostered to promote the benefits of environmental flows (e.g. implementation of a nutrient management plan to assist in reducing nutrient rich runoff).

4.2 Components of natural flow

Flow regimes in many Australian streams vary between years, seasons, months, weeks and days. This variation is important for ecological and geomorphological processes (Poff, *et al.*, 1997; Puckridge, *et al.*, 1998; Richter, *et al.*, 1997), but river regulation has substantially reduced the magnitude and variation of discharge in many streams. The FLOWS method for determining environmental flow requirements (DNRE, 2002) describes specific components that characterise the natural flow range and variability within a particular system and uses these components to link hydrological and ecological processes within that ecosystem. More simply it identifies components of the natural flow regime that are important for environmental assets within a particular system and makes recommendations to restore essential components that have been lost through regulation.

This section describes important flow components for the Wimmera and Glenelg Rivers and discusses how they affect ecological and geomorphological processes in these systems.

4.2.1 Periods of cease-to-flow

The cessation of flow is a common natural occurrence in Australian lowland rivers. During these periods the river may contract to a series of isolated pools thus decreasing the diversity and availability of aquatic habitats to instream biota. Furthermore biota in these pools may be subject to intensified predation and physicochemical stresses (e.g. low dissolved oxygen concentration and high conductivity see Table 4-1). These factors may have an immediate detrimental effect on aquatic flora and fauna, but they are important disturbance mechanisms that prevent the system being dominated by any particular group of organisms. Cease-to-flow periods are likely to contribute to macroinvertebrate community diversity over the longer term and may affect the spatial distribution of macrophytes and other plants that rely on specific wetting and drying cycles.

Regulation has increased the duration of cease-to-flow periods in the Glenelg River downstream of Rocklands Reservoir and in the Wimmera River downstream of Huddleston Weir. Prolonged cease-to-flow periods severely reduce the extent of aquatic habitats and exacerbate water quality impacts in remaining pools. This increases the physiological stress on aquatic biota, which leads to depauperate rather than diverse macroinvertebrate and fish communities. Extended cease-to-flow periods can also allow riparian and semi aquatic flora to encroach further into the main river channel, and change the structure of algae and diatom communities.

Under current operating rules, water is transferred from Lakes Lonsdale and Bellfield to Pine and Taylors Lakes via the Wimmera River. As a result, natural cease-to-flow periods have virtually been eliminated from the Wimmera River between Glenorchy Weir and Huddleston Weir. Flow through this reach maintains the quality and quantity of aquatic habitats, which is important for established fish populations, but may lead to lower macroinvertebrate and algal diversity. The reduced frequency of cease-to-flow periods may also favour exotic fish species that are not adapted to ephemeral conditions. These fish are then likely to prey on or compete with native fish and invertebrates. Constant low flow through this reach has also scoured a notch within the channel that may reduce bank stability and habitat heterogeneity.

4.2.2 Low flows

Under natural flow conditions the Wimmera and Glenelg Rivers would have periods of low flow as well as periods of cease-to-flow during summer and autumn. However regulation has reduced the magnitude and duration of low flows in these systems.

Most native fish in the Wimmera and Glenelg inhabit either slow flowing or still water, but rely on snags, macrophytes and overhanging banks for cover. Low flows help to maintain water levels and surface water quality within pools, which reduces the stress on biota that live in these habitats. Maintaining water quality in pools throughout the summer reduces the impact of sudden temperature, EC and DO changes that can accompany flushing flows (Anderson, Morrison, 1989e). Low flows also inundate bars between pools and associated snags and macrophytes, which increases habitat availability and diversity and allow biota to migrate between pools to search for limited resources or to escape habitats with poor water quality or unfavourable biotic interactions. Runs also provide diverse flow and substrate habitats that can sustain populations of Mountain galaxias that rely on flowing environments and provide important breeding habitats for various macroinvretebrates and small-bodied fish.

Winter and spring low flows are also important because they inundate large woody debris, low level wetlands and other in-channel habitats for an extended period. Animals may use these habitats during winter, spring and early summer and then seek refuge in pools during summer and autumn, but without these flows many animals would not be able to survive in these streams.

4.2.3 Freshes during periods of cease-to-flow/low flow

Summer rainfall events would naturally result in freshes in the Wimmera and Glenelg Rivers during low and cease-to-flow periods, but under the current flow regime they are absent from the Wimmera River downstream of Huddleston Weir. Summer freshes replenish aquatic habitats and maintain or improve water quality in ephemeral rivers.

Summer freshes are unlikely to cause mixing of the saline pools that characterise the middle and lower reaches of the Wimmera and Glenelg Rivers. Andrew Western demonstrated that flows of 500-2000 ML/d were required to mix saline pools depending on the volume and depth of the pool, but that pools re-stratified a few weeks after these flushes (Western, 1994). Nevertheless, summer freshes are likely to prevent significant increases in salinity that occurs at sustained low flows (SKM, 1997).

Summer freshes directly or indirectly affect native fish, macroinvertebrate, algae and macrophyte populations. Summer freshes may also provide breeding cues for some native fish and allow adults, larvae and juveniles to migrate between habitats and reaches. River blackfish, Murray cod, Macquarie perch and Dwarf galaxias lay their eggs on gravel, snag or macrophyte substrates, but do not tolerate silt and sediment smothering these habitats. Summer freshes flush sediments and silt from the substrate and as a result may increase egg survival and subsequent recruitment rates. Macroinvertebrates and algae are also more likely to colonise substrates that are not covered in silt, and may benefit from the redistribution of organic matter that occurs during periodic higher flows. Summer freshes also periodically wet macrophytes and riparian vegetation within the main river channel and therefore allow them to persist through summer.

4.2.4 Spring freshes

Spring freshes are larger than summer freshes and therefore may be more important for channel forming processes. Spring freshes also provide important spawning and migration cues for various native fish. Regulation has reduced the frequency and magnitude of spring freshes in the Wimmera and Glenelg Rivers.

Spring freshes inundate and redistribute sediments across in-channel habitats such as vegetated bars, benches and undercuts. Spring freshes may therefore be important for plant growth and maintaining geomorphological channel features, but are unlikely to last long enough to allow macroinvertebrates and fish to colonise higher habitats.

Spring freshes provide migration and spawning cues for golden perch and possibly Murray cod, Macquarie perch and Variegated pygmy perch. Freshes also help to disperse fish eggs and larvae downstream. Non-migrating fish may take advantage of temporary habitats during spring freshes and organic material washed into rivers during freshes may aid the survival and recruitment of their larvae.

4.2.5 High flows

Bank-full flows represent disturbances that occur naturally in the Wimmera and Glenelg River systems. Although bank-full flows are unpredictable and episodic (Anderson and Morison 1989a, b), they provide lateral connectivity between in-channel and flood plain habitats. Maintaining occasional inundation of the flood plain is ecologically important and provides significant carbon returns to the river, which may be critical in maintaining food webs in systems that experience periods of low and cease-to-flow conditions (Davies *et al.* 2001).

High flow regimes including bank-full flows are also important geomorphologically. They shape and maintain river, anabranch and distributary channels and also preserve the condition and availability of instream habitats. For example, bank-full flows re-suspend and re-distribute sediments that would otherwise smother important benthic habitats such as large woody debris and leaf packs.

As with spring freshes, high bank-full flows in winter and spring facilitate fish passage between reaches. This is especially important in the Glenelg River, where several species migrate between marine and freshwater environments. Lamprey, Tupong, Short-finned eels and Spotted galaxids migrate to the sea during winter and spring high flows. Bank-full flows are also important for the maintenance and regeneration of riparian vegetation. Many of the Mallee's riparian species are adapted to extended periods without water, but rely on soaking flows during winter and spring to survive.

4.2.6 Overbank flows

Overbank flows connect the main river with its floodplain. These flows are particularly important for maintaining floodplain wetlands and facilitate nutrient, sediment and carbon exchange between terrestrial habitats, wetlands and the river. Some fish and macroinvertebrates move into inundated floodplain habitats during overbank flows and then return to the main river channel as water's recede. Overbank flows also wash large woody debris and other organic material into the main river channel that provides important habitat and food for fish and macroinvertebrates. River Red Gums and floodplain understorey species rely on overbank flows to regenerate, while many water birds rely on natural flooding cycles for food, habitat and to breed. Overbank flows in the Wimmera River are particularly important for maintaining the ecology of the terminal lakes.

Rocklands Reservoir, Lake Bellfield and Lake Lonsdale trap run-off from the Grampians and partially reduce the frequency of overbank flows in the Wimmera and Glenelg Rivers, but most in-stream structures do not affect overbank flows. The overall frequency of overbank flows has been reduced in the Wimmera and Glenelg Rivers, but water savings from the Wimmera-Mallee Pipeline and existing infra-structure are not sufficient to provide and overbank environmental flow release. As such, this report does not consider these flows and potential effects in the terminal lakes in any detail.

- **Table 4-1 Water quality parameters and their effect on fish.**

Parameter	Effect on fish
Suspended sediment	High levels kill fish, smother spawning sites and eggs, cause physiological stress, affect feeding (particularly predatory, visual feeders) and smother substrates that may otherwise support algal and macroinvertebrate production that provide food resources for fish.
Temperature	Levels outside a species tolerance range will affect metabolic rate of organisms, affect spawning, incubation times and other specific life cycle and physiological requirements.
Dissolved oxygen	Essential for respiration. Low and high concentrations can kill fish and reduce access to areas of suitable habitat. Thermal stratification can reduce access to the bottom of deep pools, black water conditions can develop following a large influx of organic material and force fish and other aquatic organisms to leave the affected area.
Salinity	Can make conditions unsuitable for freshwater fish and hence reduce access to habitat. Different species and life cycle stages have different salinity tolerances.
Nutrients	Elevated nutrients can lead to eutrophication. Where nutrients are limiting, primary production may be reduced and this may restrict food availability. Elevated nutrients may not harm fish directly, but the consequences of eutrophication to general ecosystem health may negatively impact on fish through a range of different pathways.
Toxins	Can cause death, stress and abnormalities in different life cycle stages. Some toxins bioaccumulate in fish, particularly predatory fish.

4.3 Specific environmental objectives for the Wimmera and Glenelg Catchments.

The Stressed Rivers Reports for the Wimmera (SKM, 2002a) and Glenelg (SKM, 2002b) Rivers identified flow limited assets for each catchment and reviewed previous studies to determine general flow components that influence their ecology. The following tables summarise environmental management objectives for assets that will be targeted by environmental flow releases and links these objectives to relevant flow components. More detailed about these environmental management objectives and all flow dependent assets within the Wimmera and Glenelg catchments are provided in the Wimmera Bulk Entitlement Investigation (SKM, 2003a).

- **Table 4-2 Environmental management objectives for the Wimmera Catchment**

Environmental Objective	Target feature	Relevant Flow Component
Native Fish		
Maintain self-sustaining populations of River blackfish and Short-finned eel	Habitat for subsistence Recruitment / Breeding	Seasonal Low flows throughout the year Spring / summer Freshes
Restore self-sustaining populations of Murray cod, golden perch and Macquarie Perch.	Habitat for subsistence Recruitment / Breeding Movement	Seasonal Low flows throughout the year Winter / Spring Freshes Winter / Spring High Flows
Maintain self sustaining populations of Common galaxias	Habitat for subsistence Recruitment / Breeding	Seasonal Low flows throughout the year Autumn High Flow
Maintain self sustaining populations of Mountain galaxias, Western carp gudgeon, Southern pygmy perch, Flat-headed gudgeon, Australian smelt and Freshwater catfish.	Habitat for subsistence	Seasonal Low flows throughout the year
Macroinvertebrates		
Maintain self sustaining populations of Yabby, Western Cray, Freshwater shrimp, Pea mussel and South-eastern river mussel.	Habitat for subsistence	Seasonal Low flows throughout the year
Restore self sustaining populations of Glenelg Spiny Cray	Habitat for subsistence	Seasonal Low flows throughout the year
Restore macroinvertebrate community composition towards a reference condition.	Habitat for subsistence	Seasonal Low flows throughout the year
Benthic Community Diversity	Disturbance	Summer Cease-to-flow
Riparian vegetation		
Maintain Lizard orchid, Swamp billy-button, Dwarf flat-sedge, Swamp diuris, Yarra Gum, Purple eyebright, Small-leaf-sea-heath, Fused glasswort, Button rush, Six-point arrowgrass and Tiny arrowgrass communities.	Riparian	Winter Bankfull Flows
Aquatic vegetation		
Maintain Western water-starwort Communities	Habitat for subsistence	Seasonal Low Flows throughout the year

Habitat processes		
Restore longitudinal connectivity	Habitat	Winter High flows Spring Bankfull flows
Organic matter transport	Habitat	Spring High flows
Rehabilitate channel form	Sediment movement to increase habitat heterogeneity Channel forming	High and Bankfull flows at any time of the year Bankfull flows
Water Quality		
Improve water quality in pools	Slowed decline Mixing	Summer / Autumn low flow Summer / Autumn freshes
River Health		
Improve ISC scores for River Health Assessment. Environmental flows will primarily affect index components such as Aquatic Life, Water Quality and possibly Physical Form.	Habitat for subsistence Mixing Sediment movement	All flow components

Table 4-3 Environmental management objectives for the Glenelg Catchment -

Environmental Objective	Target feature	Relevant Flow Component
Native Fish		
Maintain self-sustaining populations of River blackfish (including the upper Wannon form) and Short-finned eel	Habitat for subsistence	Seasonal Low Flows throughout the year
	Recruitment / Breeding	Spring / summer Freshes
Maintain self-sustaining populations of Pouched lamprey, Short-headed lamprey and golden perch: and Restore self-sustaining populations of Macquarie Perch.	Habitat for subsistence	Seasonal Low Flows throughout the year
	Recruitment / Breeding	Winter / Spring Freshes
	Movement	Winter / Spring High Flows
Maintain self-sustaining populations of Spotted galaxias and Tupong	Habitat for subsistence	Seasonal Low Flows throughout the year
	Recruitment / Breeding	Autumn / Winter Freshes
	Movement	Winter / Spring High Flows
Maintain self-sustaining populations of Australian grayling	Habitat for subsistence	Seasonal Low Flows throughout the year
	Recruitment / Breeding	Autumn / Spring Freshes
	Movement	Winter / Spring High Flows
Maintain self sustaining populations of Common galaxias	Habitat for subsistence	Seasonal Low flows throughout the year
	Recruitment / Breeding	Autumn High Flow
Maintain self sustaining populations of Mountain galaxias (including the lower Glenelg form), Dwarf galaxias, Western carp gudgeon, Southern pygmy perch, Variegated pygmy perch, Yarra pygmy perch, Flat-headed gudgeon and Australian smelt.	Habitat for subsistence	Seasonal Low flows throughout the year
Macroinvertebrates		
Maintain self-sustaining populations of Yabby, Glenelg spiny cray, Western Cray, Western swamp cray, Freshwater shrimp, Upland burrowing cray, Portland burrowing cray, Freshwater mussel, Glenelg freshwater mussel and Pea mussel.	Habitat for subsistence	Seasonal Low flows throughout the year
Restore macroinvertebrate community composition towards a reference condition.	Habitat for subsistence	Seasonal Low flows throughout the year

Benthic Community Diversity	Disturbance	Summer Cease-to-flow
Riparian vegetation		
Maintain River swamp wallaby-grass, Lax twig-sedge, Swamp flax-lily, Bog gum, Rough eyebright, Lime fern, Swamp greenhood and Violet bladderwort communities.	Riparian	Winter Bankfull Flows
Aquatic vegetation		
Maintain Dark mignonette-orchid Communities	Habitat for subsistence	Seasonal Low Flows throughout the year
Habitat processes		
Restore longitudinal connectivity	Habitat	Winter High flows Spring Bankfull flows
Organic matter transport	Habitat	Spring High flows
Rehabilitate and maintain diversity of channel form	Sediment movement to increase habitat heterogeneity Channel forming	High and Bankfull flows at any time of the year Bankfull flows
Water Quality		
Improve water quality in pools	Slowed decline Mixing	Summer / Autumn low flow Summer / Autumn freshes
River Health		
Improve ISC scores for River Health Assessment. Environmental flows will primarily affect index components such as Aquatic Life, Water Quality and possibly Physical Form.	Habitat for subsistence Mixing Sediment movement	All flow components

Environmental management objectives have also been developed for native floodplain vegetation communities and various native bird species that are impacted by the reduction in overbank flows within the Wimmera Catchment. Floodplain flora rely on periodic flooding for growth and regeneration, while reduced flow to the floodplain wetlands has reduced the quality and quantity of habitat for significant waterbird populations. Floods also provide breeding cues and increase the availability of resources that affect the breeding success of birds such as the Great egret, Intermediate egret, Little egret, Hardhead, Brolga, Royal spoonbill and Glossy Ibis. Specific management objectives for these and other floodplain species are described in more detail in the Wimmera Bulk Entitlement Investigation, but water savings derived from the construction of the Wimmera Mallee Pipeline will not be used for overbank flows and therefore they are not considered further in this report.

In most cases, environmental flow releases aim to restore components of the natural flow regime (i.e. flow that would occur without water diversions or storage) to maintain or restore populations of native flora and fauna. However, non-flow related factors also impact biota within the Wimmera and Glenelg Catchments. These impacts may confound the response of biota to prescribed flow releases. For example, artificial barriers such as Rocklands Dam and Huddleston Weir prevent the migration and recruitment of certain fish species, which reduces the likelihood that populations will become self-sustaining even if appropriate flow regimes are restored. Ecological management objectives also need to consider potential negative impacts associated with environmental flows. Extensive land clearing has contributed to elevated salt and sediment loads in both the Wimmera and Glenelg Rivers. Large flushing flows that scour sediment from one habitat only to smother other habitats further downstream, or that flush saline pools only to produce a toxic salt dose further downstream may have little if any net environmental benefit. Similarly prescribed cease-to-flow periods may lead to unnaturally high salt levels in permanent pools that may kill native fauna or flora that the environmental flows are intended to benefit. In these cases, natural flow components may be omitted from environmental flow recommendations.

5. Water Allocations and flow rules designed to meet objectives and targets.

SKM (SKM, 2003b) developed environmental flow recommendations for individual reaches in the Wimmera and Glenelg River systems to address the environmental objectives described in the previous section. These recommendations take into account existing and historical environmental assets in each reach, changes due to regulation and also try and incorporate potential flow releases in reaches further upstream. The aim of these flow recommendations is to restore key components of the natural flow regime rather than use artificial flow regimes to ameliorate environmental stresses such as increased salinity. It must be stressed that these are only recommendations and at this stage there has been no clear decision about how water savings from the Wimmera-Mallee Pipeline will be allocated.

5.1 Flow recommendations for the Wimmera River

Sinclair Knight Merz developed flow recommendations for four reaches in the Wimmera River, two reaches in the MacKenzie River and Burnt Creek and a single reach in Mt William Creek. These recommendations are summarised below, but a more comprehensive description and the rationale behind them is presented in the Wimmera Bulk Entitlement report (SKM, 2003b).

5.1.1 Upper Wimmera River (above Glenorchy)

The Upper Wimmera River above Glenorchy is naturally ephemeral, although there are also some semi-permanent spring-fed tributaries. There are no water transfers from this uppermost reach, although some abstraction for stock and domestic does occur and these abstractions have increased (compared to natural) the duration and frequency of zero and low flows. During natural summer low flows, pools become important refuges for biota, especially fish, so these changes in flow regime will reduce the availability of key habitat during summer. High salinity and potentially low dissolved oxygen in pools during summer are also important issues for this reach (SKM, 2002c).

The objectives of environmental flows in this reach are to mimic aspects of the natural flow regime, especially freshes during summer and spring, to reinstate fish passage through instream barriers and restore longitudinal connectivity, and to maintain self-sustaining populations of key native fish species (River Blackfish, Mountain Galaxias, Flathead Gudgeon and Australian Smelt). Flow recommendations to meet these objectives include minimum summer low flows (2-4 ML/day), with prescribed cease-to-flow events and freshes, minimum flows (16-27 ML/day) during the transitional months of June and November, winter low flows (20-50 ML/day) and various winter high flow events (up to 3900 ML/day for 2 days) (SKM, 2002c).

The summer low flows maintain connectivity and water quality in pools, and the high flow events in winter are primarily to support River Blackfish populations by providing biological cues for movement. Cease-to-flow events are only prescribed for the most upstream section of the Wimmera River and some tributaries.

The Wimmera-Mallee Pipeline may reduce the need for direct abstractions from the Wimmera River upstream of Glenorchy, which would provide more water for the environment. However, since there are no transfers or in channel flow control structures, no environmental flow releases will be provided for this reach. As a result, this reach may be used in the monitoring program as a control to compare the effect of environmental flow releases in the Wimmera River immediately downstream of Glenorchy, which has similar physical characteristics. The use of potential controls for the monitoring program will be discussed in more detail in Chapter 7.

5.1.2 Wimmera River Reach 1 (Glenorchy to Huddleston Weir)

Stream flow in this reach is currently ephemeral and would have been so naturally. However, water transfers from the eastern storages (Lakes Lonsdale, Bellfield and Fyans) flow between Glenorchy and Huddleston Weirs on route to Pine and Taylors Lakes. As a result, flow in the Wimmera River between Glenorchy Weir and Huddleston Weir is higher than natural at certain times of the year. A major objective for this reach is the reintroduction of cease-to-flow periods that mimic natural frequencies and duration.

Environmental flow recommendations for reach 1 are summarised in Table 5-1.

- **Table 5-1 Environmental flow recommendations for the Wimmera River: Glenorchy to Huddleston Weir.**

<table>
<tr><th>River</th><th colspan="3">Wimmera River</th><th>Reach 1</th><th colspan="2">Glenorchy - Huddleston</th></tr>
<tr><th colspan="2">Compliance Point</th><th colspan="2">Glenorchy</th><th colspan="2">Gauge No.</th><th>415201</th></tr>
<tr><th colspan="4">Flow</th><th colspan="3">Rationale</th></tr>
<tr><th>Season</th><th>Magnitude</th><th>Frequency</th><th>Duration</th><th colspan="3">Objective</th></tr>
<tr><td>Summer</td><td>0 ML/day</td><td>Annually</td><td>15-34 Days</td><td colspan="3">Natural stress to promote macroinvertebrate biodiversity</td></tr>
<tr><td></td><td>Minimum flow 6 ML/day</td><td>Annually</td><td>Dec – May
(excluding specified CTF)</td><td colspan="3">Maintain quality and quantity of habitat for native fish, macroinvertebrates, aquatic vegetation.</td></tr>
<tr><td></td><td>> 16 ML/day</td><td>3 annually</td><td>Minimum 5 days</td><td colspan="3">Enhance recruitment of Short finned eels and River Blackfish</td></tr>
<tr><td>Winter</td><td>25 ML/day
Minimum passing flow</td><td>Daily</td><td>July - November</td><td colspan="3">Inundate snags and other elements that provide habitat for native fish, macroinvertebrates and aquatic vegetation, and maintain longitudinal connectivity.</td></tr>
<tr><td></td><td>Minimum 10% Inflows Passed</td><td>Daily</td><td>July - November</td><td colspan="3">As above</td></tr>
<tr><td>Annual</td><td>5,500 ML/day</td><td>Annual</td><td>Minimum 5 days</td><td colspan="3">Provide high flows to cue and enhance recruitment of golden perch, Murray cod and Macquarie perch, maintain riparian vegetation and habitat for native bird species and facilitate channel forming processes.</td></tr>
</table>

Cease-to-flow events are important for macrophyte communities to recolonise habitats, and are a disturbance to aquatic macroinvertebrate communities that reset the succession processes to maintain a diverse community. The timing and duration of the recommended cease-to-flow period are aimed to mimic natural conditions so that the stress, caused in this case by too much flow, is not exacerbated. The maximum cease-to-flow period is set at 34 days so that water quality in residual pools does not deteriorate enough to kill the native fish community.

A minimum summer low flow of 6 ML/day is recommended to provide low level connectivity between pools to prevent the loss of water quality (e.g. salinity, dissolved oxygen) along the reach. This reach has a high native fish and macrophyte community diversity, maintaining the habitat quality is important to maintain these communities. A flow of 6 ML/day allows a minimum depth through the reach of approximately 13 cm, this would not be effective for longitudinal fish movement but is sufficient to maintain habitat quality.

Summer freshes should be introduced to increase flow variability and wet important in-channel habitats. The recommended flow (> 16 ML/day) is unlikely to flush stratified pool water and exacerbate water quality further downstream, but monitoring is recommended to assess downstream water quality. Prescribed flow volumes may need to be adjusted if water quality is adversely affected.

Constant winter low flows are a key stressor through this reach. They have cut a distinct channel at the level of the regulated flow and this has lead to erosion, bank slumping and habitat loss. Returning the variability to this flow should be a priority. Flow variability will also allow some of the lower benches to be wet and provide a flow that links habitats through the reach to allow fish movement. A minimum of 10% of current inflows, with a minimum flow of 25 ML/day, is suggested as a starting point for the translucent releases from Glenorchy Weir. The greater the percentage of natural inflows that are allowed to pass Glenorchy Weir the greater the benefit to the downstream reach. It has been suggested that 100% of inflows may be passed in some circumstances (J. Martin, Wimmera-Mallee Water pers. comm.).

The recommended large flow event (5,500 ML/day) is the size that the average annual flood event would have naturally been in this reach. It is not a bankfull event but has sufficient volume and depth to provide key channel forming processes. These large flows will redistribute organic matter and sediments and thoroughly wet all in-channel habitats.

5.1.3 Wimmera River Reach 2/3 (Huddleston Weir to MacKenzie River confluence).

The key stress in this reach is the impact of Huddleston Weir, which effectively prevents all low to medium flows passing downstream. Cease-to-flow events would occur naturally in this reach, but they are artificially extended by the diversion of all flows less than 1,600 ML/day at Huddleston Weir.

Environmental flow recommendations are summarised in Table 5-2.

- **Table 5-2 Environmental flow recommendations for the Wimmera River: Huddleston Weir to MacKenzie River confluence.**

<table>
<tr><th>River</th><th colspan="3">Wimmera River</th><th>Reach 2</th><th colspan="2">Huddleston – MacKenzie River</th></tr>
<tr><th colspan="2">Compliance Point</th><th colspan="2">Faux Bridge</th><th colspan="2">Gauge No.</th><th>415240</th></tr>
<tr><th colspan="4">Flow</th><th colspan="3">Rationale</th></tr>
<tr><th>Season</th><th>Magnitude</th><th>Frequency</th><th>Duration</th><th colspan="3">Objective</th></tr>
<tr><td>Summer</td><td>0 ML/day</td><td>Annually</td><td>17 – 30 days</td><td colspan="3">Natural stress to promote macroinvertebrate biodiversity</td></tr>
<tr><td></td><td>Minimum flow 6 ML/day</td><td>Annually</td><td>Dec – May
(excluding specified CTF)</td><td colspan="3">Maintain quality and quantity of habitat for native fish, macroinvertebrates, aquatic vegetation.</td></tr>
<tr><td></td><td>> 16 ML/day</td><td>3 annually</td><td>7 - 15 days</td><td colspan="3">Enhance recruitment of Short finned eels and River Blackfish</td></tr>
<tr><td>Spring
July – Nov</td><td>> 164 ML/day</td><td>2 – 3 annually</td><td>Minimum 14 days</td><td colspan="3">Maintain riparian vegetation and habitat for native bird species.</td></tr>
<tr><td></td><td>Minimum flow 60 ML/day</td><td>Annually</td><td>July – November</td><td colspan="3">Inundate snags and other elements that provide habitat for native fish, macroinvertebrates and aquatic vegetation, and maintain longitudinal connectivity.</td></tr>
<tr><td>Annual</td><td>6,000 ML/day</td><td>Annual</td><td>Minimum 2 days</td><td colspan="3">Provide high flows to cue and enhance recruitment of golden perch, Murray cod and Macquarie perch, maintain riparian vegetation and habitat for native bird species and facilitate channel forming processes.</td></tr>
</table>

Cease-to-flow periods are artificially long in this reach and the prescribed flow recommendations aim to return the maximum cease-to-flow period to its natural range. It is recommended that the annual cease-to-flow period should not exceed 34 days. This period is expected to preserve residual pools, which provide important refuges for endemic fish and macroinvertebrates. Species that persist in these pools can recolonise other channel habitats when flows return.

Minimum summer low flows are recommended for this reach to connect pools at a very low trickle, which will maintain their water volume and quality. The recommended minimum flow of 6 ML/day provides a small flow (< 20 cm) over the high points in the reach. This flow would not be sufficient for fish passage but would maintain water within the pools.

Summer freshes should be returned to the system. The median natural summer flow was 8 ML/day but to be consistent, and restore some connection with the upper reach, the recommended summer fresh is 16 ML/day. The recommended flow of greater than 16 ML/day would be unlikely to result in whole scale mixing of the stratified pools but as for Reach 1, this should be monitored to ensure downstream water quality is not affected. Summer freshes naturally lasted for a median of 15 days, the minimum recommended duration is seven days and there should be three events per year. This will wet some in-channel habitats and refresh the pools.

It is important that minimum flows during the winter-spring period allow uninhibited fish movement through the stream. There are no obligate migrating fish species in this reach, but longitudinal connectivity is important for mobile species such as Mountain galaxias and River blackfish. The specified minimum flow (60 ML/day) for the high flow period will inundate critical habitats and low-lying regions in the channel (SKM, 2002a).

Several fish species in this reach that are thought to require spring flow events to trigger spawning or migration. The magnitude and duration of the recommended spring freshes are based on the median of natural spring events and should therefore provide adequate biological triggers. Two or three events are recommended each spring to provide alternative events for the fish community. Golden perch are found through this reach and reinstatement of this flow component will increase the likelihood of this population becoming self-sustaining. However, other factors may limit golden perch passage and spawning in this reach and therefore small-bodied endemic fish may be better indicators of the effectiveness of spring freshes.

As for reach 1 the high flow recommended is an annual event that has the capacity for channel maintenance, sediment movement and the redistribution of organic matter. The natural annual high flow event was approximately 6,000 ML/day (SKM, 2003b). The Wimmera channel has incised over recent time and therefore it is hard to determine whether a 6,000 ML/day flow would have naturally been a bankfull or overbank flow.

The environmental flow recommendations described here relate to the whole reach between Huddleston Weir and the confluence with the MacKenzie River. However, environmental flows can potentially be released from Huddleston Weir (if the structure is modified) or the Lake Taylor outlet and the release point will determine how much of the reach receives extra water. The Lake Taylor outfall has been used for previous environmental flow releases in the Wimmera River, but it enters the Wimmera River about half way between Huddleston Weir and the MacKenzie River. Flow releases from this outfall therefore affect the lower half of the reach but do not improve conditions in the upper half of the reach and do not provide longitudinal connectivity with other reaches further upstream. Huddleston Weir is the uppermost part of the reach and releases from this point would affect the entire reach, but the weir would need to be substantially modified to deliver the recommended environmental flows. If environmental flows are released from the

Taylors Lake outlet, then this reach may need to be split into two for the proposed monitoring program.

5.1.4 Wimmera River Reach 4/5 (MacKenzie River confluence to Lake Hindmarsh)

Pumping extraction is the only direct water management in the Wimmera River downstream of MacKenzie River. Flow through this reach is primarily affected by operations in MacKenzie River and Burnt Creek and management actions further upstream such as Huddleston Weir.

The downstream reach of the Wimmera River has a natural cease-to-flow period, but permanent water persists in large pools. Flow recommendations for this reach suggest that the cease-to-flow period should not exceed that which would have occurred under natural conditions. A supporting recommendation is made to prevent further extraction during this period. This will ensure that the cease-to-flow period is not unnaturally extended. It is important to note that cease-to-flow recommendations should not be implemented while any existing saline groundwater intrusion issues are unresolved.

Table 5-3 illustrates the environmental flow recommendations for this reach. These are interim recommendations and will be finalised following the calculation of Yarriambiack Creek flows.

- **Table 5-3 Environmental flow recommendation for the Wimmera River: MacKenzie River confluence to Lake Hindmarsh.**

River	Wimmera River			Reach 4 / 5	MacKenzie R – Lake Hindmarsh
Compliance Point		Dimboola		Gauge No.	415243
Flow				Rationale	
Season	Magnitude	Frequency	Duration	Objective	
Summer	0 ML/day	Annually	5 –24 Days	Natural stress to promote macroinvertebrate biodiversity	
	Minimum flow 5 ML/day	Annually	Dec – May (excluding specified CTF)	Maintain quality and quantity of habitat for native fish, macroinvertebrates, aquatic vegetation.	
	> 20 ML/day	4 annually	7 - 15 days	Enhance recruitment of River blackfish	
Spring July – Nov	> 334 ML/day	5 annually	Minimum 14 days	Enhance recruitment of golden perch, River Blackfish, Short-finned eel, provide habitat for Mountain galaxias and wet off-stream habitats.	
	Minimum flow 34 ML/day	Annually	July – November	Inundate snags and other elements that provide habitat for native fish, macroinvertebrates and aquatic vegetation, and maintain longitudinal connectivity.	
Annual	> 3,000 ML/day	Annual	Minimum 2 days	High flows to flush saline pools and facilitate channel forming processes	
Annual	6,000 ML/day	Annual	3 - 5 days	High flows to facilitate channel forming processes and maintain riparian vegetation and bird habitat.	

The minimum summer flow is the flow that has been shown hydraulically to provide a low flow throughout the habitats (SKM, 2003b).

Summer and spring freshes are the key flow components that need to be restored. A minimum period of 7 days is set for the summer freshes. These events would have naturally occurred three or four times per year. The current recommendation is for four summer freshes per year. Winter/spring events would have naturally been more frequent and therefore five events are recommended each year. Large events greater than 3,000 ML/day are recommended in line with previous studies by Anderson and Morrison (1989).

5.1.5 MacKenzie River between the Mt Zero Off-take Channel and Distribution Heads

Complex system operations mean that adjoining reaches of the MacKenzie River have very different flow regimes. Flow recommendations have been made for the section downstream of the Mt Zero off-take as this is considered to be under the most stress. Environmental flow recommendations for this section are summarised in Table 5-4.

- **Table 5-4 Environmental flow recommendation for the MacKenzie River between the Mt Zero Off-take Channel and Distribution Heads.**

River	**MacKenzie River**		**Reach**	**Downstream Lake Wartook**
Compliance Point			**Gauge No.**	
Flow				**Rationale**
Season	**Magnitude**	**Frequency**	**Duration**	**Objective**
Summer	0 ML/day	Maximum 5 annually	Maximum 7 days each	Natural stress to promote macroinvertebrate biodiversity
	2 ML/day	Annual	When not cease-to-flow	Maintain quality and quantity of habitat for native fish, macroinvertebrates, aquatic vegetation.
	> 5 ML/day	5 annually	5 days	Enhance recruitment of Short finned eels and River Blackfish
Winter	Minimum flow 27 ML/day	Daily	July – November	Inundate snags and other elements that provide habitat for native fish, macroinvertebrates and aquatic vegetation, and maintain longitudinal connectivity.
	> 75 ML/day	Minimum 3 annually	Minimum 7 days	Provide high flows to cue and enhance recruitment of golden perch, Murray cod and Macquarie perch, maintain riparian and floodplain vegetation and habitat for native bird species and facilitate channel forming processes.
Annual	1,700 ML/day	1 in 4-5 years	Minimum 1 day	Overbank flows to maintain floodplain vegetation communities and provide habitat and breeding cues for native birds

Under the current flow regime, there are no cease-to-flow events in this reach of the MacKenzie River although cease-to-flow events would occur under natural conditions. Natural cease-to-flow periods would not be long enough to dry out sections of the bank. Up to five short cease-to-flow periods are recommended each year to preserve permanent pools that are important habitats within the reach.

Low flows are recommended to be 2 ML/day. This is higher than natural low flows, but is considered important to maintain the condition of pool habitats through summer for native fish. This flow will not provide longitudinal connectivity, but will help to retain water in critical habitats.

Five summer freshes of 5 ML /day are recommended to provide inputs to pools after cease-to-flow events and to wet low lying habitats. These flows reflect natural median flows and should benefit aquatic and emergent vegetation within the reach. .

A minimum winter flow of 27 ML/day was chosen as it wets the full channel without breaking out onto the benches (SKM, 2003b). This flow will ensure longitudinal connectivity that is important for fish movement. Vegetation within the channel will also benefit from the large wetted area.

Winter freshes will provide biological cues for native fish, cover low benches and inundate emergent vegetation and move organic matter and sediment through the reach. At least three winter freshes are recommended. This is less than the natural frequency (SKM, 2003b), but will provide multiple events for biological triggers. Freshes should last for at least seven days to adequately wet vegetation and to allow fish communities to respond to cues.

5.1.6 MacKenzie River downstream of Distribution Heads

Most flow from the upper reaches of the MacKenzie River are diverted at Mt Zero Channel or Distribution Heads. Local catchment runoff is the main source of flow in the MacKenzie River downstream of Distribution Heads. The total volume of flow and the duration and frequency of events in this section of the MacKenzie River is substantially lower than natural levels and the duration of cease-to-flow periods has increased (SKM, 2003b). Flow recommendations for this reach of the MacKenzie River are summarised in Table 5-5.

- **Table 5-5 Environmental flow recommendation for the MacKenzie River, downstream Distribution Heads.**

River	**MacKenzie River**			**Reach**	**Downstream Distribution Heads**
Compliance Point				**Gauge No.**	
Flow				**Rationale**	
Season	**Magnitude**	**Frequency**	**Duration**	**Objective**	
Summer	0 ML/day	Maximum 5 annually	Maximum 7 days each	Natural stress to promote macroinvertebrate biodiversity	
	2 ML/day	Annual	When not cease-to-flow	Maintain quality and quantity of habitat for native fish, macroinvertebrates, aquatic vegetation.	
	> 5 ML/day	5 annually	7 days	Enhance recruitment of Short finned eels and River Blackfish	
Winter	Minimum flow 37 ML/day	Daily	July – November	Inundate snags and other elements that provide habitat for native fish, macroinvertebrates and aquatic vegetation, and maintain longitudinal connectivity.	
	> 100 ML/day	Minimum 3 annually	Minimum 7 days	Provide high flows to cue and enhance recruitment of golden perch, Murray cod and Macquarie perch, maintain riparian and floodplain vegetation and habitat for native bird species and facilitate channel forming processes.	
Annual	1,700 ML/day	1 in 4-5 years	Minimum 1 day	Overbank flows to maintain floodplain vegetation communities and provide habitat and breeding cues for native birds	

Frequent, but short, cease-to-flow events are recommended to preserve pools within this reach. These pools provide important habitat for native fish and other aquatic species. Summer low flows of 2 ML/day will deemed important to retain water and sustain water quality in pools in this reach.

Five summer freshes of 5 ML /day (equating to natural median flow) are recommended to replenish pools after cease-to-flow events and to wet low lying habitats. These flushes should last for at least seven days, which is the natural median duration (SKM, 2003b).

A minimum winter flow of 37 ML/day was chosen as it wets the full channel without breaking out onto the benches (SKM, 2003b). This flow corresponds to the natural 80% flow for this reach and is in parity with the flow recommendations for upstream reaches. This flow will wet a significant range of instream habitats and will facilitate longitudinal connectivity, which will allow fish movement through the reach. Vegetation within the channel will also benefit from this flow.

Winter freshes will provide biological cues for native fish, cover low benches and inundate emergent vegetation and move organic matter and sediment through the reach. At least three winter freshes are recommended. This is less than the natural frequency (SKM, 2003b), but will provide multiple events for biological triggers. Freshes should last for at least seven days to adequately wet vegetation and to allow fish communities to respond to cues.

5.1.7 Mt William Creek between Lake Lonsdale and Wimmera River

Trudgeons Weir (3km downstream of the Lonsdale dam wall) diverts most flow (up to 350 ML/day) down the Main Central Inlet Channel to Glenorchy Weir. Flows are artificially high upstream of Trudgeons Weir, but are significantly reduced downstream of the Weir.

Environmental flow recommendations for Site 1 are summarised in Table 5-6.

- **Table 5-6 Environmental flow recommendation for Mt William Creek between Lake Lonsdale and Wimmera River.**

River	**Mt William Creek**			**Reach 1**	**Downstream Lake Lonsdale**
Flow				**Rationale**	
Season	**Magnitude**	**Frequency**	**Duration**	**Objective**	
Summer	0 ML/day > 5 ML/ day	Annually 3 annually	Max 48 Days 5 days	Natural stress to promote macroinvertebrate biodiversity Enhance recruitment of Short finned eels and River Blackfish	
Winter	29 ML / day Minimum passing flow	Daily	June - November	Inundate snags and other elements that provide habitat for native fish, macroinvertebrates and aquatic vegetation, and maintain longitudinal connectivity.	
Winter	> 143 ML / day	2 annually	July – October Minimum 7 days	Provide high flows to cue and enhance recruitment of golden perch, Murray cod and Macquarie perch, maintain riparian and floodplain vegetation and habitat for native bird species and facilitate channel forming processes.	

This reach would normally be relatively dry in summer and therefore no summer low flows are prescribed. Three small summer events are recommended to ensure that the cease-to-flow period does not exceed 48 days, and these events should be managed to ensure the timing of the first cease-to-flow period varies each year. Small summer flushes of at least 5 ML/day are considered sufficient to maintain water quality in pools that are used by small-bodied native fish. Flushes should last for five days and it is important that no extractions occur during these events.

A winter low flow of 29 ML/day is recommended to provide continuous flow through the reach. This will ensure longitudinal connectivity and allow small fish to move throughout the reach. Additional winter freshes (> 143 ML/day) are recommended to wet a large cross section of the creek and to mobilise organic matter and sediment. Large flows also provide cues for native fish and therefore multiple events are recommended each year. Flows that last for seven days should provide adequate cues and also mobilise sediments. It is important to provide shoulders on either side of the high flow events to reduce the chance of erosion.

5.1.8 Burnt Creek below Toolondo Channel

Under natural conditions, Burnt Creek would have been a flood distributary of MacKenzie River and would have also received ephemeral run-off from its own catchment. Wimmera Mallee Water currently uses Burnt Creek to transfer flow from Distribution Heads to Toolondo Channel. There is no flow in Burnt Creek downstream of Toolondo Channel unless flow exceeds capacity in that channel. A small flow is also released in February and March to fill some farm dams.

Flow recommendations for this reach are summarised in Table 5-7.

- **Table 5-7 Environmental flow recommendations for Burnt Creek below Toolondo Channel.**

River	**Burnt Creek**			**Reach**	**Downstream Distribution Heads**
Compliance Point				**Gauge No.**	
Flow				**Rationale**	
Season	**Magnitude**	**Frequency**	**Duration**	**Objective**	
Summer	0 ML/day	Annually	4 months	Natural stress to promote macroinvertebrate biodiversity	
	>45 ML/day	1 in 2 years	Minimum 1 day	Enhance recruitment of Short finned eels and River Blackfish	
Winter	Minimum flow of 1 ML / day	Daily	May - December	Inundate snags and other elements that provide habitat for native fish, macroinvertebrates and aquatic vegetation, and maintain longitudinal connectivity.	
	> 2 ML/day	2 annually	June – October Minimum 5 day duration	Provide high flows to cue and enhance recruitment of golden perch, Murray cod and Macquarie perch and maintain riparian vegetation.	
Annual	45 ML/day	3 annually	Minimum 2 day duration	Provide high flows to cue and enhance recruitment of golden perch, Murray cod and Macquarie perch, maintain riparian vegetation and facilitate channel forming processes.	

Aquatic communities cannot be sustained in this section of Burnt Creek under the current flow conditions. Flow recommendations for this reach are intended to facilitate the return of aquatic biota.

It is recommended that the cease-to-flow period last a maximum of four months, which corresponds to the median duration of the natural events (SKM, 2003a). Organic matter accumulates in the channel during these long dry periods and larger flows are required to redistribute this material and fill deep areas in the channel. There is no recommendation for summer low flows, these would not occur naturally and may be considered an environmental threat in this reach.

Minimum flow of 1 ML/day is recommended between May and December to maintain and link aquatic habitats. This flow would replenish pools and increase the likelihood that they will persist through summer. These habitats may then support small native fish such as Gudgeon and Pygmy perch. Winter freshes (> 2 ML/day) are required to wet channel habitats and vegetation stands in backwaters and anabranches, and provide connectivity that will facilitate fish movement between pools. At least two winter freshes are recommended each year to provide cues for native fish such as Mountain Galaxias. Three channel full flows of 45 ML/day are recommended each year to provide connectivity through the full length of the stream, move sediments and redistribute larger material (SKM, 2003a). These flows may already occur under current conditions because Distribution Heads and other regulators do not have the capacity to hold high volumes during large events. The benefits of these larger flows are mainly physical and therefore they probably only need to last for two days at a time.

5.1.9 Burnt Creek between Distribution Heads and Toolondo Channel

Under natural conditions this section of Burnt Creek would have been mainly ephemeral and only received overbank flows from MacKenzie River and run-off from the local catchment. This reach is now used to transfer water from Distribution Heads to Toolondo Channel and has permanent water and elevated summer flows.

Flow recommendations for this reach are the same as the reach downstream of Toolondo Channel and are summarised in Table 5-8.

- **Table 5-8 Environmental flow recommendation Burnt Creek between Distribution Heads and Toolondo Channel.**

<table>
<tr><th>River</th><th colspan="3">Burnt Creek</th><th>Reach</th><th colspan="2">Downstream Distribution Heads</th></tr>
<tr><th colspan="2">Compliance Point</th><th colspan="2"></th><th colspan="2">Gauge No.</th><th></th></tr>
<tr><th colspan="4">Flow</th><th colspan="3">Rationale</th></tr>
<tr><th>Season</th><th>Magnitude</th><th>Frequency</th><th>Duration</th><th colspan="3">Objective</th></tr>
<tr><td>Summer</td><td>0 ML/day</td><td>Annually</td><td>4 months</td><td colspan="3">Natural stress to promote macroinvertebrate biodiversity</td></tr>
<tr><td></td><td>>45 ML/day</td><td>1 in 2 years</td><td>Minimum 1 day</td><td colspan="3">Enhance recruitment of River Blackfish</td></tr>
<tr><td>Winter</td><td>Minimum flow of 1 ML / day</td><td>Daily</td><td>May - December</td><td colspan="3">Inundate snags and other elements that provide habitat for native fish, macroinvertebrates and aquatic vegetation, and maintain longitudinal connectivity.</td></tr>
<tr><td></td><td>> 2 ML/day</td><td>2 annually</td><td>June – October
Minimum 5 day duration</td><td colspan="3">Provide high flows to cue and enhance recruitment of golden perch, Murray cod and Macquarie perch and maintain riparian vegetation.</td></tr>
<tr><td>Annual</td><td>45 ML/day</td><td>3 annually</td><td>Minimum 2 day duration</td><td colspan="3">Provide high flows to cue and enhance recruitment of golden perch, Murray cod and Macquarie perch, maintain riparian vegetation and facilitate channel forming processes.</td></tr>
</table>

Permanent water is unnatural in this reach but now supports a high value fish community (SKM, 2003a). The introduction of some low flow and cease-to-flow periods to this reach should not overly impact these native fish communities, but would help to maintain other ecosystem function.

The key recommendation is to extend the cease-to-flow period and allow the winter flow recommendations to provide water for the channel. Cease-to-flow periods should last up to four months, should not be implemented until existing saline groundwater intrusion issues are resolved.

5.2 Flow recommendations for the Glenelg River

Sinclair Knight Merz developed flow recommendations for three reaches in the Glenelg River and for the First and Second Wannon Creeks downstream of the diversion weirs. These recommendations are summarised below, but a more comprehensive description and the rationale behind them is presented in the Glenelg Stressed Rivers Report and the Wimmera Bulk Entitlement report (SKM, 2002b; 2003a).

5.2.1 Glenelg River upstream of Rocklands Reservoir

The Glenelg River upstream of Rocklands Reservoir flows through a swampy valley with relatively ill defined channels and wetlands (SKM, 2003b). Much of the river flows through the Grampians National Park and has an intact riparian zone. Moora Moora Reservoir traps some run-off from the Grampians that would normally flow to the Glenelg River. This reservoir has a capacity of 6,290 ML, which WMW divert to Distribution Heads via the Moora Channel (capacity 50 ML/day) (SKM, 2003b). Water can also be diverted directly from the Glenelg River to the Moora Channel at two points four and twelve kilometres downstream of the reservoir. Passing flows can be released back to the Glenelg River, but this only occurs when the reservoir is full. There are no records of the actual volume of water diverted from this section of the Glenelg River, which makes it difficult to evaluate impacts to the natural flow regime, but current operations are likely to affect low flows. Fire dams on the Glenelg River and its tributaries are also likely to restrict fish passage.

The Glenelg River upstream of Rocklands Reservoir supports at least four species of native fish including dwarf galaxias, which is a FFG listed species. The main flow recommendation for this reach is that there be no summer extractions to protect key habitats for high value fish species. Environmental flow recommendations for this reach are summarised in Table 5-9.

- **Table 5-9 Environmental flow recommendation for the Glenelg River upstream of Rocklands Reservoir.**

River	Glenelg River	Reach	Upstream of Rocklands Reservoir
Flow		Rationale	
Season	Recommendation	Objective	
Summer (Dec – May)	No Diversions during low flows	Maintain quality and quantity of instream and wetland habitat for native fish, macroinvertebrates, aquatic vegetation.	
	Pass first two summer freshes	Maintain quality and quantity of instream and wetland habitat for native fish, macroinvertebrates, aquatic vegetation.	
Winter (July – Oct)	Minimum winter flow of 10ML/day	Inundate snags and other elements that provide habitat for native fish, macroinvertebrates and aquatic vegetation, and maintain longitudinal connectivity.	
	Pass first two winter freshes	Maintain quality and quantity of instream and wetland habitat for native fish, macroinvertebrates, aquatic vegetation.	

Water savings from the Wimmera Mallee Pipeline may reduce abstraction pressures on this reach of the Glenelg River, but at present there is no indication of the likely savings for this reach.

5.2.2 Glenelg River between Rocklands Reservoir and Chetwynd River

Rocklands Reservoir has substantially reduced flow in this section of the Glenelg River and are likely to affect the reproduction and recruitment of native aquatic biota among other impacts. The long-term recommendation is to introduce a translucent dam operation at Rocklands Reservoir that will more effectively provide the required flow components and variability. In the meantime, flow recommendations will need to be implemented directly. Environmental flow recommendations for this reach are summarised in Table 5-10.

- **Table 5-10 Environmental flow recommendation for the Glenelg River between Rocklands Reservoir and Chetwynd River.**

<table>
<tr><th>River</th><th colspan="3">Glenelg River</th><th>Reach</th><th colspan="2">Rocklands – Chetwynd River</th></tr>
<tr><th colspan="2">Compliance Point</th><th colspan="2">Compliance Point</th><th colspan="2">Harrow</th><th>Gauge No.</th></tr>
<tr><th colspan="4">Flow</th><th colspan="3">Rationale</th></tr>
<tr><th>Season</th><th>Magnitude</th><th>Frequency</th><th>Duration</th><th colspan="3">Objective</th></tr>
<tr><td>Summer
(Dec – May)</td><td>Minimum 11 ML/day</td><td>Annual</td><td>Dec – May</td><td colspan="3">Maintain quality and quantity of habitat for native fish, macroinvertebrates, aquatic vegetation.</td></tr>
<tr><td></td><td>> 64 ML/day</td><td>5 times annually</td><td>Minimum 6 days</td><td colspan="3">Enhance recruitment of Short-finned eels and River Blackfish</td></tr>
<tr><td>June</td><td>100 ML/day</td><td>Annual</td><td>June</td><td colspan="3">Inundate snags and other elements that provide habitat for native fish, macroinvertebrates and aquatic vegetation, and maintain longitudinal connectivity.</td></tr>
<tr><td>Winter
(July – Oct)</td><td>Minimum
150 ML/day</td><td>Annual</td><td>July-Oct</td><td colspan="3">Inundate snags and other elements that provide habitat for native fish, macroinvertebrates, aquatic vegetation and birds, and maintain longitudinal connectivity.</td></tr>
<tr><td></td><td>> 1400 ML/day</td><td>3 times annually</td><td>3 days</td><td colspan="3">High flows to provide breeding cues and facilitate migration of native fish, provide habitat and breeding cues for birds, maintain riparian and floodplain vegetation and facilitate channel forming processes.</td></tr>
<tr><td>November</td><td>130 ML/day</td><td>Annual</td><td>November</td><td colspan="3">Inundate snags and other elements that provide habitat for native fish, macroinvertebrates, aquatic vegetation and birds, and maintain longitudinal connectivity.</td></tr>
<tr><td>Spring
(July – Nov)</td><td>> 450 ML/day</td><td>2 times annually</td><td>10 days</td><td colspan="3">High flows to facilitate the recruitment of native fish, maintain floodplain and riparian vegetation and restore longitudinal connectivity.</td></tr>
</table>

Under the current system, this section of the Glenelg River has a short (less than one week) cease-to-flow period every year. Natural flow conditions would have included longer and more frequent cease-to-flow periods. However, salinity is a major concern in this reach and therefore cease-to-flow periods are not recommended for this reach.

The existing minimum flow recommendation is for a passing flow of 11 ML/day at Harrow (Mitchell, *et al.*, 1996). This should be retained as the minimum summer flow as it links the key habitats through the reach (SKM, 2003a) and reduces the impact of saline intrusions (Mitchell, *et al.*, 1996). In addition five summer freshes (64 ML/day) are recommended each year to wet habitats on channel bars, provide flow through pools that will reduce saline stratification.

Minimum winter flows (150 ML/day) are recommended to provide continuous flow and habitat connectivity through the reach. These flows will also wet channel margins and low lying bars that may support emergent vegetation. Spring and winter freshes (>450 ML/day) are also recommended to provide spawning and movement cues for aquatic biota and to wet other parts of the channel. At least two freshes should occur each year to allow for biological responses, they should last for at least 10 days to maximise the likelihood that biota will respond.

Three high winter flows (greater than 1400 ML/day) are recommended each year to wet all major habitats in the reach and to mobilise sediments. These flows are intended to influence physical processes. Most physical processes are affected by the first flush and therefore these high flows only need to last for three days. Larger channel filling flows are important for wetting other habitats including mid channel bars. These would only occur when Rocklands Reservoir spills and are not prescribed under these environmental flow recommendations.

There are substantial differences between Summer and Winter/Spring flow recommendations. Therefore the flow recommendations include a gradual ramping up and down of flow during June and November respectively.

Natural variation between wet and dry years may prevent the implementation of flow recommendations every year. Therefore managers should aim to implement the average annual flow recommendations over a five-year period.

Under the current system, environmental flows can be released from the Rocklands Reservoir dam wall, five mile outlet and twelve mile outlet. Releases from each of these locations or a combination of all three can be used to achieve target discharge rates downstream at Harrow (SKM, 2002d), but releases from five mile and twelve mile outlets may deprive the upper section of this reach of flow. If flows are released from either five mile or twelve mile outlet then the monitoring program may need to consider the upper and lower sections of this reach separately.

5.2.3 Glenelg River between Chetwynd River and Wannon River

Inputs from unregulated rivers reduce the impact from Rocklands Reservoir through this section of the Glenelg River, but some effects remain and licenced extractions also influence flow. Environmental flow recommendations for this reach are summarised in Table 5-11, but flow releases from Rocklands Reservoir are unlikely to have much effect in this reach and therefore these flow recommendations will not necessarily be delivered through savings from the Wimmera-Mallee Pipeline.

- **Table 5-11 Environmental flow recommendations for the Glenelg River between Chetwynd River and Wannon River**

River	**Glenelg River**		**Reach**	**Rocklands – Chetwynd River**
Compliance Point	**Roseneath**		**Gauge No.**	**238 211**
Flow				**Rationale**
Season	**Magnitude**	**Frequency**	**Duration**	**Objective**
Summer (Dec – May)	0 ML/day	3 times annually	Maximum 8 days	Natural stress to promote macroinvertebrate biodiversity
	Minimum 16-77 ML/day	Annual	Dec – May (excl. CTF)	Maintain quality and quantity of habitat for native fish, macroinvertebrates, aquatic vegetation.
	> 77 ML/day	4 times annually	7-15 days	Improve water quality and habitat for native fish.
June	93 ML/day	Annual	June	Inundate snags and other elements that provide habitat for native fish, macroinvertebrates and aquatic vegetation, improve water quality in pools and maintain longitudinal connectivity.
Winter (July – Oct)	Minimum 385 ML/day	Annual	July-Oct	Inundate snags and other elements that provide habitat for native fish, macroinvertebrates and aquatic vegetation, improve water quality in pools and maintain longitudinal connectivity.
	> 3600 ML/day	2 times annually	Min 4 days	High flows to provide breeding cues and facilitate migration of native fish, provide habitat and breeding cues for birds, facilitate channel forming processes and provide a natural disturbance to reset macroinvertebrate communities.

<table>
<tr><th>River</th><th colspan="3">Glenelg River</th><th>Reach</th><th colspan="2">Rocklands – Chetwynd River</th></tr>
<tr><th colspan="2">Compliance Point</th><th colspan="2">Roseneath</th><th colspan="2">Gauge No.</th><th>238 211</th></tr>
<tr><th colspan="4">Flow</th><th colspan="3">Rationale</th></tr>
<tr><th>Season</th><th>Magnitude</th><th>Frequency</th><th>Duration</th><th colspan="3">Objective</th></tr>
<tr><td>November</td><td>110 ML/day</td><td>Annual</td><td>November</td><td colspan="3">Inundate snags and other elements that provide habitat for native fish, macroinvertebrates and aquatic vegetation, improve water quality in pools and maintain longitudinal connectivity.</td></tr>
<tr><td>Spring
(Sept)</td><td>> 700 ML/day</td><td>2-3 times annually</td><td>5 days</td><td colspan="3">High flows to facilitate the recruitment and migration of native fish, maintain floodplain and riparian vegetation and restore longitudinal connectivity.</td></tr>
</table>

Three cease-to-flow events are recommended each year to provide an environmental disturbance that will enhance macroinvertebrate diversity. These events should last no more than eight days, which reflects the natural duration, as longer events are likely to adversely impact the system. However, cease-to-flow events are likely to exacerbate water quality issues, particularly salinity problems, in permanent pools. Therefore no cease-to-flow events should be implemented until water quality is improved throughout the reach.

A summer minimum flow of 16 ML/day is recommended to provide connectivity between habitats in the reach (SKM, 2002b). Connecting flows increase mixing in permanent pools, which improves temperature, dissolved oxygen and salinity levels. The recommended flows are equivalent to recommended summer flows in the reach upstream of Chetwynd River, after allowing for other tributary inflows. An average of four summer freshes of 77 ML/day are recommended each year to mix pools and minimise the risk of saline pools forming.

Winter minimum flows of 385 ML/day are recommended to maintain flow over a range of in channel habitats. These flows are expected to improve pool water quality, which will benefit aquatic fauna. Two large, flushing flows greater than 3600 ML/day are recommended to mobilise sand within the reach. This should be done in conjunction with mechanical sand extraction to prevent further infilling downstream.

Spring freshes greater than 700 ML/day are recommended to provide spawning and migration cues for native fauna including fish. These freshes should last at least five days and occur two to three times per year to increase the likelihood of a biological response.

Flows should be gradually ramped up in June and down in November to minimise the impact of sudden changes between low summer and high winter/spring flow levels.

5.2.4 Glenelg River between Wannon River and the Tidal Extent

Rocklands Reservoir has minimal impact on Glenelg River flows downstream of Wannon River. Licensed channel extractions and farm dams are the main flow impacts, while sediment inputs from land clearing have substantially affected in channel habitats. Environmental flow releases from Rocklands Reservoir as a result of savings from the Wimmera-Mallee Pipeline are not expected to have an effect in this reach of the Glenelg River and are therefore not considered in this report.

5.2.5 Wannon River

Flow in the upper reaches of the Wannon River is affected by weirs on the First and Second Wannon Creeks that can divert all but the largest flows to Lake Bellfield in the Wimmera Catchment. At present, there are no diversions during summer, but winter flows are substantially reduced. Flows through the middle and lower reaches of the Wannon River are relatively unaffected.

Flow recommendations for the upper reaches of the Wannon River, below the diversion weirs are summarised in Table 5-12.

- **Table 5-12 Flow recommendations for First and Second Wannon Creeks.**

Flow component	Change to Flow Regime under current conditions	Environmental Impact of Current Regime	Recommendation	Objective
Cease-to-flow	No change	Excess stress on fauna	No summer diversions (continue current regime)	Provide natural disturbance to maintain diversity of benthic macroinvertebrate community
Low flow	No change (summer)	Decrease in aquatic habitats	No summer diversions (continue current regime)	Maintain quality and quantity of habitat for native fish, macroinvertebrates and aquatic vegetation
	Reduced (winter)	Decrease in aquatic habitats	Minimum flow 10 ML/day	Maintain quality and quantity of habitat for native fish, macroinvertebrates and aquatic vegetation and allow movement of native fish between habitats
Summer Fresh	No change	Impact on fish recruitment	No summer diversions (continue current regime)	Facilitate fish recruitment
High flow	Decreased volume	Impact on fish movement and riparian vegetation	Winter (June – November inclusive), minimum 10ML/day flow	Facilitate fish movement, maintain aquatic and riparian vegetation communities and floodplain habitat.
Winter fresh	Not present	Impact on fish recruitment	Winter fresh 3 times per year, duration 5 days, minimum volume 30 ML/day	Provide cues and movement opportunities for native fish recruitment.

Under natural conditions, low flows would maintain permanent pools that would provide habitat for small bodied fish (SKM, 2002b). The recommendation for this reach is to continue the current regime of no summer diversions, which will allow aquatic species to survive. A minimum winter flow of 10 ML/day is recommended to provide habitat and three winter freshes of at least 30

ML/day are recommended to wet wider riffle and channel habitats and to provide cues for fish and macroinvertebrates (SKM, 2002b).

6. Review of existing data and identify knowledge gaps

The environmental flows monitoring program will aim to detect and measure environmental changes associated with flow releases in the Wimmera and Glenelg Catchments. In order to assess the nature and extent of any changes, it is necessary to identify environmental assets that are likely to be affected by flow changes and to determine the current condition of these assets. The final monitoring program will recommend some data collection prior to the full allocation of environmental flows, but previous studies and historical data will also be useful.

Several studies have monitored ecological responses to small environmental flow releases in the Wimmera and Glenelg Rivers. Anderson and Morison (Anderson, Morrison, 1989e) monitored water quality changes associated with an experimental flow release in the MacKenzie and Wimmera Rivers in March 1987. Zampatti *et al.* (Zampatti, *et al.*, 1997) assessed fish, macroinvertebrate and water quality assets in the Wimmera catchment during and after the 1994/95 environmental flow releases. Mitchell *et al.* (Mitchell, *et al.*, 2002) monitored macroinvertebrate and water quality changes to environmental flow releases in the Wimmera and Glenelg Rivers between 1997 and 2002. The Zampatti *et al* (Zampatti, *et al.*, 1997) and Anderson & Morison (Anderson, Morrison, 1989e) monitoring programs were too short to assess broad ecological changes due to environmental flow releases. The proposed flow releases will also be much larger and may enter the system at different locations than the previous releases, therefore the results of previous monitoring programs may not accurately indicate future changes. Nevertheless, these and other routine condition assessment programs may provide a good indication of environmental condition under various flow regimes.

The following tables highlight previous studies that may provide a useful assessment of environmental conditions in parts of the Wimmera and Glenelg catchments under various flow regimes and prior to the release of the proposed environmental flows.

- **Table 6-1 Description of previous and ongoing monitoring programs and environmental studies in the Wimmera River System, including the number of study sites within each river reach.**

Previous Data & Studies	Wimmera River: U/S Glenorchy	Wimmera River: Glenorchy - Huddleston	U/S Lake Taylor outl	D/S Lake Taylor outl	Wimmera River: MacKenzie – Hindmarsh	MacKenzie River: U/S Dist. Heads	MacKenzie River: D/S Dist. Heads	Mt William Creek: D/S Lake Lonsdale	Burnt Creek: U/S Toolondo Channel	Burnt Creek: D/S Toolondo Channel
Water Quality										
VWQMN sites: DO, EC, pH, Temp, Turbidity, Suspended Solids, Total Phosphorus	2	1		1	1	1	1	1		
Anderson & Morison: Nutrients and depth profiles (DO, EC, Temp) measured 4 times between 1986-7. Specific location of sites unknown.	15	7	6	18						
Mitchell & Lind: Measured instantaneous discharge, Temp, DO, EC (4-6 sampling periods per season – 5 seasons 1997/98 to 2001/02.	1				3					
Water EcoScience: Measured EC, pH, DO, Temp in-situ on 3 occasions 94/95. Data available in 1997 report		1		1	2	1	2	1		
Hydrology										
VWQMN sites: Most sites have average daily flow since 1980s	2	1		1	3	1	1	1	1	
Biology										
Fish										
Anderson & Morison: Abundance and CPUE data from 1986 (presented in 1989 report).	2	1		4	8		2	3	2	1

Previous Data & Studies	**Wimmera River: U/S Glenorchy**	**Wimmera River: Glenorchy - Huddleston**	**U/S Lake Taylor outl**	**D/S Lake Taylor outl**	**Wimmera River: MacKenzie – Hindmarsh**	**MacKenzie River: U/S Dist. Heads**	**MacKenzie River: D/S Dist. Heads**	**Mt William Creek: D/S Lake Lonsdale**	**Burnt Creek: U/S Toolondo Channel**	**Burnt Creek: D/S Toolondo Channel**
Water EcoScience: Seine net samples on 3 occasions 94/95. Abundance of different development stages. Data available in 1997 report		1		1	2	1	2	1		
Arthur Rylah Institute: Electrofished area for 2001 BE study. Qualitative species list data. No specific site locations given.		✓	✓		✓	✓	✓	✓	✓	✓
Invertebrates										
EPA NRHP: Rapid Bioassessment sweep samples, live picks and family level ID.	6	1	1	2	12	4	3	2		
EPA NRHP (Reference sites): Rapid Bioassessment sweep samples, live picks but ID to lowest taxonomic level.	1	1		1	4	1	1	1		
Water EcoScience: Sweep net samples, 10% subsampled and ID to lowest taxonomic level. Samples on 3 occasions 94/95. Data available in 1997 report.		1		1	2	1	2	1		
Mitchell & Lind: Sampled snag, macrophyte and sand separately in pools and riffles on 4-6 occasions each year from 1997/98 – 2001/02	1				3					
EPA: Quantitative airlift samples taken between 1985 – 2002.				1	2					

Previous Data & Studies	**Wimmera River: U/S Glenorchy**	**Wimmera River: Glenorchy - Huddleston**	**U/S Lake Taylor outl**	**D/S Lake Taylor outl**	**Wimmera River: MacKenzie – Hindmarsh**	**MacKenzie River: U/S Dist. Heads**	**MacKenzie River: D/S Dist. Heads**	**Mt William Creek: D/S Lake Lonsdale**	**Burnt Creek: U/S Toolondo Channel**	**Burnt Creek: D/S Toolondo Channel**
Physical habitat assessment										
Water EcoScience: Physical description and habitat assessment at each site 94/95. No Quantitative assessment therefore not very useful. Written description in 1997 report.		1		1	2	1	2	1		
SKM: Cross section surveys and physical habitat description prepared for BE report in 2001. 6-9 cross sections per site.		1	2	2	3	1	1	1	1	1
Anderson & Morison: Detailed cross section survey and habitat descriptions in 1986. But data not available and exact location of sites unknown	14	6	8	15	52	2	17	7	5	8

- **Table 6-2 Description of previous and ongoing monitoring programs and environmental studies in the Glenelg River System, including the number of study sites within each river reach.**

Previous Data & Studies	Glenelg River U/S Rocklands	Glenelg River: Rocklands – Chetwynd	Glenelg River: Chetwynd - Wannon	Glenelg River: Wannon – Tidal Extent	Wannon River
Water Quality					
VWQMN sites: DO, EC, pH, Temp, Turbidity, Suspended Solids, Total Phosphorus	1	2		2	4
Mitchell & Lind: Measured instantaneous discharge, Temp, DO, EC (4-6 sampling periods per season – 5 seasons 1997/98 to 2001/02.		3	1		
Hydrology					
VWQMN sites: Most sites have average daily flow since 1980s	1	2		2	4
SKM: Determination of water losses and transmission time lags associated with flow releases from Rocklands Reservoir. This was a one-off assessment in 2001/02.		5	1		
Biology					
Fish					
Arthur Rylah Institute: Electrofished area for 2001 BE study. Qualitative species list data. No specific site locations given.		✓	✓	✓	✓
Invertebrates					
EPA NRHP: Rapid Bioassessment sweep samples, live picks and family level ID. Standard monitoring for ISC assessment.	2	3	3	3	7

EPA NRHP (Reference sites): Rapid Bioassessment sweep samples, live picks but ID to lowest taxonomic level.	1	1	1	2	3
Mitchell & Lind: Sampled snag, macrophyte and sand separately in pools and riffles on 4-6 occasions each year from 1997/98 – 2001/02		3	1		
Mitchell et al 1996: Quantitative data – 5 replicate cylinder sampler samples from each site collected during low flow in January 1996 Qualitative data – 10 minute sweep net sample across all habitats at each site on 4 occasions between Jan – April 1996		6	3		1 (3 km US Glenelg River).
Plants					
Mitchell et al 1996: Qualitatively assessed distribution of plants and macrophytes at each site. Written descriptions are provided in report.		6	3		1
Physical Habitat Assessment					
SKM: Cross section surveys and physical habitat description prepared for BE report in 2001. 6-9 cross sections per site.		4	3	2	2* (not full cross sections).

6.1 Water Quality

Water quality varies over a range of temporal scales and therefore frequent monitoring is required to accurately characterise the condition of a particular stream or river reach.

Electrical Conductivity, Dissolved Oxygen, pH, Turbidity, Temperature, Nutrients and metals are monitored monthly at Victorian Water Quality Monitoring Network (VWQMN) sites. Most of the VWQMN sites in the Wimmera and Glenelg catchments have been active since the 1970s or 1980s and therefore provide a good indication of conditions prior to environmental flow releases and can continue to be used to assess temporal changes associated with future flow releases. VWQMN sites are currently being monitored in all of the key reaches identified in the Wimmera and Glenelg

Rivers except for Burnt Creek and the Glenelg River between Chetwynd River and Wannon River, but monitoring may not necessarily occur in key habitats within each reach.

One of the main threats to environmental assets in the Wimmera and Glenelg systems is the increase in salinity and decrease in dissolved oxygen in deep pools during low and cease-to-flow periods. Most of the VWQMN sites monitor water quality conditions in the upper layers of the water column. The Rural Water Corporation of Victoria (RWC) operated continuous salinity monitors at various depths in deep pools at Lower Norton and Big Bend in the lower Wimmera River between at least 1992 and 1995. The RWC also manually measured vertical salinity profiles in another pool at Lower Norton and pools at Polkemmet and Tarranyurk in the Lower Wimmera over this same period. This data has been reported in Andrew Western’s Ph.D. thesis and shows that flows between 500 ML/day and 2000 ML/day are required to mix saline pools of varying depths, but smaller flows improve DO and EC levels at the surface water of these pools (Western, 1994). This data may also provide useful baseline data for monitoring the proposed environmental flow releases. VWQMN monitoring may provide baseline data and be used to assess water quality changes at the surface of pools in the Wimmera and Glenelg Rivers due to environmental flows. However, additional monitoring will probably be needed to assess changes to water quality at depth throughout these systems.

Various other studies (e.g. (Anderson, Morrison, 1989e; Mitchell, 2001; Mitchell, *et al.*, 2002; Zampatti, *et al.*, 1997) have measured water quality (DO, EC, pH, Temperature and Turbidity) at specific sites in the Wimmera and Glenelg catchments. These studies generally measured water quality in pools, but in most cases samples were only taken on a few occasions or in a couple of years and therefore may be of little use for assessing changes associated with environmental flows. The most useful of these studies is probably the environmental flow assessment conducted by Brad Mitchell, Peter Lind and Ty Mathews. They monitored water quality at eight sites across the Wimmera and Glenelg catchments on up to six occasions in each of the last six summers. This data may provide a useful comparison for environmental flow releases during summer, but it will be partially compromised by the drought and the fact that small environmental flows were released throughout their study.

6.2 Hydrology

VWQMN gauging stations continuously monitor discharge and provide average daily, monthly, seasonal and annual flow data since the 1970s and 1980s. These gauging stations will be useful for assessing changes in discharge after the environmental flows are released at some sites within the Wimmera and Glenelg systems, but gauging stations are not present in all key reaches or in optimal locations within each reach. The monitoring program to assess environmental flows in the Wimmera and Glenelg Rivers may therefore need to establish gauge stations at additional sites or extrapolate information from existing sites.

It is important to determine transmission losses within a system so that flow releases can best match the environmental flow recommendations for each river reach. Estimated transmission losses have been modelled and measured for environmental flows in various reaches in the Wimmera and Glenelg Rivers. Anderson and Morison (1989e) used permanent and temporary gauging stations to measure lag times and transmission losses for experimental flow releases in the MacKenzie River and Wimmera River in 1987. They also reported lag times for the Wimmera River that were associated with a natural flood in 1981 and a controlled release to fill the re-constructed Horsham Weir in 1971 (Anderson, Morrison, 1989e). Sinclair Knight Merz (SKM, 2002d) used temporary and permanent gauging stations to measure transmission losses and flow time lags in five sections of the Glenelg River downstream of the Rocklands Reservoir dam wall, Five Mile Outlet and Twelve Mile Outlet. Data from these studies may be useful for determining how much flow has to be released to meet the recommended flows and similar studies may be needed in other reaches of the Wimmera and Glenelg Rivers to determine whether environmental releases are providing expected changes to the flow regime. Existing gauging stations may be used for some of these assessments, but more sensitive measures may be needed to detect small flow changes such as the 1-2 ML/day recommendations for Wimmera tributaries such as the MacKenzie River and Burnt Creek.

6.3 Biological

Several studies have surveyed fish communities in the Wimmera and Glenelg systems. However, most of these surveys only report qualitative species list data and in many cases there is no indication of where sampling occurred and the sampling effort at each site. The Department of Sustainability and Environment flora and fauna database has fish species records from the Wimmera and Glenelg systems, but this data is not validated and is not up to date. Staff from the Arthur Rylah Institute electrofished key reaches of the Wimmera and Glenelg Rivers for SKM in 2001 and 2002 as part of the Stressed Rivers studies. Anderson and Morison (1989a) used fyke and gill nets and angler surveys to assess fish populations at numerous sites throughout the Wimmera Catchment in 1986. This data is relatively quantitative and includes the number of fish caught and catch per unit effort, but the sampling methods are generally biased towards large fish. Results from the Anderson and Morison (1989) study have been published, but the raw data may need to be obtained from the Arthur Rylah Institute or Snobs Creek Freshwater Research Station if it is going to be used for temporal comparisons with current and future data. Zampatti *et al.* (1997) used fine seine nets to sample fish populations at eight sites in the Wimmera River, MacKenzie River and Mount William Creek following small environmental flow releases in 1993/94 and 1994/95. This study only sampled fish populations in one season (summer 1994/95) and therefore did not provide a good test of the environmental flow releases. However, the data records the relative abundance of different life stages for each species and may be used to compare against changes associated with future environmental flow releases that include spring and winter freshes. No data from quantitative fish surveys is available for the Glenelg system.

Environmental flows will most likely affect the relative abundance of different fish in particular habitats and therefore qualitative species lists may not be very useful for assessing changes associated with flow releases.

Macroinvertebrates are the most common biological indicator used in these and other aquatic systems. The EPA have numerous test and reference sites in the Wimmera and Glenelg catchments that they periodically monitor as part of the National River Health Program (NRHP) and state Index of Stream Condition (ISC) assessments. NRHP and ISC data is collected using qualitative rapid bioassessment techniques. Sweep samples are taken from representative habitats at each site, picked live in the field and identified to family level in the laboratory. This data is usually transformed to binary form for use in AusRivAS models and SIGNAL scores, but relative abundance categories may also be used. Samples from reference sites are collected in the same way, but are identified to the lowest practical taxonomic level and relative abundances are recorded. AusRivAS models and SIGNAL scores can be used to detect large changes in community structure, but more sensitive quantitative measures may be needed to detect macroinvertebrate responses to environmental flows (Leon Metzeling pers. comm.). Mitchell and Lind (Mitchell, Lind, 1999) highlighted differences in macroinvertebrate communities in macrophyte, snag and substrate habitats, particularly within the Glenelg River, and suggested that general sweep samples may mask some useful community patterns.

The EPA data will be useful for assessing changes in River Health after the introduction of environmental flows. ISC assessments are conducted every five to seven years and future monitoring events may indicate general effects that environmental flows have on River Health.

The EPA also quantitatively monitors macroinvertebrate communities at three sites on the Wimmera River as part of their own research program. These samples are collected with an airlift sampler, identified to the lowest taxonomic level and the resultant data can be validly expressed as the number of individuals per square metre. Mitchell *et al.* (1996) quantitatively assessed macroinvertebrate communities at ten sites in the Glenelg River in 1996 and Mitchell *et al.* (2002) intensively sampled macroinvertebrate communities at four sites in the Wimmera and Glenelg Rivers every summer between 1997 and 2002. Samples were collected from different substrates with a 30 cm corer or standard sweep net, but were quantitatively sorted in the laboratory and identified to the lowest practical taxonomic level. Quantitative data from the EPA and Mitchell *et al.* (1996 & 2002) studies are likely to provide a good reference against which to compare macroinvertebrate community responses to environmental flows.

There is very little data on the distribution and abundance of plants and algae in the Wimmera and Glenelg Rivers. A few studies such as Mitchell *et al.* (Mitchell, *et al.*, 1996) and Anderson and Morison (Anderson, Morrison, 1989d) described plant communities and some of the most common macrophytes and algae that occurred at various sites on the Wimmera and Glenelg Rivers. However without any data, this information is of little use for future comparisons.

6.4 Physical:

Several studies e.g. (Mitchell, *et al.*, 1996; Zampatti, *et al.*, 1997) have described physical habitat characteristics and the geomorphological conditions at individual sites in the Wimmera and Glenelg Rivers, but such descriptions cannot be readily used to assess flow related changes. Detailed cross sections provide the most useful data. Individual cross sections can be surveyed over various time intervals to quantitatively assess changes to channel shape and instream habitats. Anderson and Morison (Anderson, Morrison, 1989a; d) extensively surveyed cross sections in the Wimmera River and its main tributaries in 1986, but the raw data is no longer available and the exact location of the cross sections is unknown. SKM measured six to nine cross sections and longitudinal profiles at various sites on the Wimmera and Glenelg Rivers in 2001/2002. These locations are still pegged and GPS co-ordinates have been recorded and they can therefore be used to assess physical changes in the channel over time and after the introduction of environmental flows. Rutherfurd and Budahazy (Rutherfurd, Budahazy, 1996) surveyed 22 channel cross sections between Deep Creek and Powers Creek on the Glenelg River and 10 cross section along a 10 kilometre section of the Glenelg River upstream of the Dartmoor Railway Bridge. These cross sections were used to assess channel morphology and in particular sand infilling within the Glenelg River for a sand management strategy (Rutherfurd, Budahazy, 1996).

7. Monitoring Program for Wimmera and Glenelg Rivers

7.1 Hypotheses and contrasts – philosophy of the design

Environmental flows represent a restoration activity designed to rehabilitate parts of a river ecosystem assumed to have been altered or degraded by a regulated flow regime. Environmental flow recommendations for a river usually set hydrological targets for specific components of the hydrograph, such as minimum summer low flows and cease-to-flow events, spring freshes, and winter high flow events. This is certainly the case for the Wimmera and Glenelg Rivers, where the Stressed Rivers and Bulk Entitlement studies have focused on these components. Nonetheless, if the environmental flow recommendations are implemented, the result is a changed flow regime representing a combination of the modified flow components.

In practice it would be difficult to design a monitoring program to test responses to individual flow components. Such assessments would require that water be re-allocated to the river in a very experimental manner, e.g. allocating individual flow components to some reaches and not others, or comparing conditions before and after particular flow events. Even then, one “event” is not independent of those that precede or follow, so only short-term responses would be interpretable. Therefore, the main aim of any monitoring program associated with an environmental flow should be to determine ecological responses to the overall flow regime, rather than individual modified components. We can then use our understanding of ecological responses to particular flow components to determine whether environmental flows have delivered the required objectives.

(Downes, *et al.*, 2002) review approaches for monitoring the ecological responses to river restoration activities, and (King, *et al.*, 2003) discuss methods specifically applicable to monitoring environmental flows. The latter review emphasises three fundamental steps necessary for monitoring responses to environmental flows. First, an initial development phase must clearly articulate the objectives of the environmental flow regime and the monitoring program itself. This phase must also develop a multidisciplinary conceptual model of how the river system functions naturally, and how this functioning has changed as a result of regulation. This model should highlight likely causal links between flow and ecological response as well as identifying knowledge gaps and providing an important communication tool. Most importantly, the model will help specify the particular hypotheses to be evaluated by the monitoring program. This component of the monitoring design for the Wimmera and Glenelg Rivers has been summarised in Sections 4-6 of this report, although this summary is limited because the details of how any additional water will be re-allocated to the rivers cannot be predicted at this stage. The second step is to choose appropriate response variables that indicate ecological change in response to the environmental flow regime. These variables and the criteria for their selection will be considered below. Finally, the spatial and temporal extent and frequency of sampling these response variables need to be determined.

Two broad strategies for monitoring the effects of humans, including restoration activities, have been advocated for freshwater ecosystems. The first approach measures the condition or health of an ecosystem by comparing what is observed at a “test” site with what would be predicted if there was no (or little) human activity. These predictions are developed from a reference condition, usually based on comparable sites considered closer to pristine, and the difference between the observed and predicted condition is a measure of river health. The most common application of this method uses macroinvertebrate family presence/absence as the variable of interest. This predictive reference condition approach was not designed for establishing causal links between a particular stressor (e.g. flow) or restoration activity (e.g. environmental flow) and a response (e.g. health) but more for overall assessments of river condition, often across broad spatial scales.

The second approach has been developed for assessing the response of an ecosystem to a specific human activity, especially one that is relatively localised in spatial extent and has an identifiable starting point. The basic principles of good experiment design are used in a sampling design that measures the chosen variables both before and after the human activity commences, and at the affected site plus one or more control sites (sites without the human activity). These designs are commonly referred to as BACI (Before-After-Control-Impact) designs and are thoroughly reviewed by Downes *et al*. (2002). When the human activity is some form of restoration (e.g. environmental flows), then a combination of a BACI design with clearly identifiable restoration targets, usually determined from the reference condition (although pristine will rarely be a sensible target), is often recommended (Downes, *et al.*, 2002).

For monitoring environmental flows in the Wimmera and Glenelg Rivers, measuring changes in river health will clearly be important (e.g. have there been improvements in river health with environmental flows?), as will causally linking specific observed changes to the environmental flows (e.g. are River Blackfish populations larger as a result of the environmental flows?). However, neither of the two approaches outlined above can be simply applied to this monitoring design. The reference condition might be measurable for some reaches, e.g. the Wimmera upstream of Glenorchy is physically similar to immediately downstream without major diversions. The problem is that reference condition monitoring by itself does not easily identify causal links between changes in health and environmental flows. The BACI approach is also difficult in this system for two reasons. First, there is no clear starting point for the environmental flow regime. Environmental flows have been released in this system since 1996 and additional water as a result of the pipeline project will be allocated gradually over a number of years. So there is no simple before-after comparison. Second, the complex nature of distribution points and channels within the Wimmera system means that it is very difficult, at this stage, to predict how any environmental flows will be allocated. Therefore, it is not possible to designate control sites (sections of river comparably regulated to reaches in the Wimmera but without environmental flows). The Glenelg is simpler as environmental flows can only be released from Rocklands Reservoir, but the river upstream of this large storage is quite different to downstream so again, true controls are not available. The main tributaries to each river are not directly comparable to the Wimmera or the Glenelg because of size differences or because their flow is not regulated or regulated very differently. Finally, observations and discussions with scientists who are familiar with other rivers in the region (e.g. Avoca) suggest that other catchments are unlikely to be suitable as controls for either the Wimmera or the Glenelg. These catchments either have very different flow regulation, channel morphology or hydrology to either the Wimmera or Glenelg Rivers.

Despite the difficulties of using reference reaches to infer a causal link between flow change and ecological response, monitoring temporal trends in reference reaches will provide a measure of natural temporal variability, both short and long term. If both reference and flow-modified reaches track similarly through time for chosen variables, this will provide more confidence that future changes in flow-modified reaches are a result of environmental flows. Hence, our recommended monitoring design includes reaches that are less likely to receive major environmental water allocations.

Our overall recommendations for monitoring the ecological effects of environmental flows in the Wimmera and Glenelg Rivers are, therefore, based on detecting trends at key sites within identified reaches through time and comparing the direction and magnitude of these changes with environmental objectives that have been set for each system. Some specific contrasts between reaches may help establish causal links between flow changes and observed responses, e.g. comparing changes downstream of Glenorchy to upstream of Glenorchy. These are not true control versus impact comparisons as the Wimmera upstream of Glenorchy is not regulated like the rest of the Wimmera, but these contrasts will be part of a levels-of-evidence approach (Downes, *et al.*, 2002) to linking ecological responses to flow change. Levels-of-evidence represents a collection of different pieces of information that combine to increase our confidence that an observed response is caused by a particular management intervention, e.g. allocating environmental water. While this approach has not, to our knowledge, been formally applied to management interventions in ecosystems, it has been recommended for those situations where proper BACI designs are not possible (Downes *et al*. 2002), as is the case here. Its application to monitoring environmental flows is also the topic of active research in Australia, through the CRCFE (R. Norris, University of Canberra) and the University of Melbourne (B. Downes). The levels of evidence approach requires either accumulated evidence in support of the hypothesis that environmental flows cause the observed ecological responses and/or evidence that alternative explanations are less likely. In the Wimmera-Glenelg system, such alternative explanations might include climate change (tested by measuring concurrent temporal change in reference reaches), changing land-use practices (tested by recording major land-use changes in catchment e.g. clearing or regrowth of riparian vegetation), or marked changes in water quality, such as salinity (tested by measuring water quality in reference and flow-impacted reaches). These alternative explanations, particularly those related to restoration of the river ecosystems (e.g. revegetation, reduced salinity), need to be considered as part of the monitoring program. In the case of the Wimmera-Glenelg, monitoring reference reaches and water quality variables is critical.

Other components of the levels-of-evidence approach will include the temporal trends at key sites and on-going research, in Australia and elsewhere, examining links between flow change and ecological responses. These temporal trends will also allow some comparisons between years, especially as the environmental allocations may vary from year to year depending on whether annual allocations are accumulated or even available. It must be recognised, however, that causal links will always be difficult to establish, especially without the full BACI design, and other confounding effects in these rivers (e.g. riparian modification, changes to land practices etc.) will contribute to any ecological change.

We finish this section on a cautionary note. Environmental flows provide an excellent opportunity for adaptive management, with different flow regimes representing different management experiments that can be assessed with careful monitoring. The results of this monitoring can then be used to optimise the environmental flow regime for ecological benefit. However, such an adaptive management framework requires a long-term commitment by all stakeholders to the implementation of a designed flow regime, possibly with planned flow events to test specific hypotheses. The environmental flows for the Wimmera and Glenelg Rivers will not fit into an adaptive management framework unless such a commitment exists and an agreed flow regime is maintained. Finally, the results of any monitoring program will be difficult to interpret and of little value in an adaptive management context unless there is a clear long-term strategy that outlines how and when water will be allocated in both catchments.

7.2 Reaches and study sites

The environmental flow recommendations for the Wimmera and Glenelg Rivers are based around reaches (SKM, 2002a; b; 2003b), with specified values for flow components set for each reach. The Wimmera River has been divided into five reaches, plus there are key tributaries (Mt William and Burnt Creeks and the McKenzie River) that will also potentially receive environmental flows. The five Wimmera River reaches are: upstream of Glenorchy Weir, Glenorchy Weir to Huddleston Weir, Huddleston Weir to Mt William Creek, Mt William Creek to McKenzie River and McKenzie River to Lake Hindmarsh. Three reaches should be defined on the McKenzie River that include the Mt Zero Off-take Channel to Distribution Heads, Distribution Heads to Toolondo Channel and downstream of the Toolondo Channel. Two reaches should be defined on Burnt Creek upstream and downstream of the Toolondo Channel, but Mt. William Creek should be treated as a single reach. Note that the downstream boundaries of the tributaries are the confluences with the Wimmera River and the upstream boundaries are Lake Lonsdale for Mt William Creek, Distribution Heads for Burnt Creek, and the Mt Zero Off-take Channel for the McKenzie River. The Glenelg River was divided into three reaches, although only the first (Rocklands to Chetwynd River) is likely to be directly influenced by environmental flow releases from Rocklands Reservoir. Nonetheless, temporal trends at sites chosen using the criteria below could be measured. Some water abstraction occurs in the Glenelg River upstream of Rocklands Reservoir. However, no flow models and only general flow objectives have been developed for the Glenelg River upstream of Rocklands Reservoir, and no specific water allocations have been determined. Conditions in this reach are unlikely to change due to environmental flow releases and it is not a suitable reference for conditions downstream of Rocklands Reservoir, but we have included it in the monitoring design at the request of the Glenelg-Hopkins CMA. Wimmera and Glenelg reaches are summarised in Table 7-1.

- **Table 7-1 Environmental flow reaches in the Wimmera and Glenelg Rivers considered in this study.**

River	Reach
Wimmera River	1. Upstream of Glenorchy Weir 2. Glenorchy Weir to Huddleston Weir 3. Huddleston Weir to Lake Taylor outlet 4. Lake Taylor outlet to MacKenzie River confluence 5. MacKenzie River confluence to Lake Hindmarsh
MacKenzie River	1. Mt Zero Channel to Distribution Heads 2. Distribution Heads to Toolondo Channel 3. Toolondo Channel to Wimmera River
Burnt Creek	1. Distribution Heads to Toolondo Channel 2. Toolondo Channel to Wimmera River
Mt William Creek	1. Lake Lonsdale outlet to Wimmera River
Glenelg River	1. Upstream of Rocklands Reservoir 2. Rocklands Reservoir to Chetwynd River confluence 3. Chetwynd River confluence to Wannon River confluence 4. Wannon River confluence to Dartmoor
Wannon River	1. Upper reaches

Contrasts between specific reaches will provide stronger evidence that observed changes are a result of environmental flows. For example, the Wimmera River reach upstream of Glenorchy is unregulated and is unlikely to receive environmental flows (although flows may change as a result of reduced abstraction recommended under the Streamflow Management Plan for the Upper Wimmera). Therefore, this reach provides a record of natural change in key variables, independent of environmental flows and can be used to separate this change from responses to environmental flows in comparable reaches, such as Glenorchy to Huddleston.

It should be noted that the environmental flow recommendations for each reach were based on hydrological and ecological data from only one or two sites in that reach. An implicit assumption is that these sites are representative of the rest of the reach and this assumption will also apply to the monitoring program. The selection of sites for monitoring should be based on how well they represent a reach, the availability and quality of existing ecological information, and their proximity to gauging stations and Victorian Water Quality Monitoring Network stations.

A significant decision for the monitoring program is the number of sites per reach. The focus of our design is on temporal trends at key sites, and the power of these tests for trends is based on the number of sampling times. However, there are two reasons why more than one replicate site per reach is also inferentially important. First, environmental flow recommendations for the Wimmera-Glenelg have been made on a reach by reach basis so we would want any monitoring of responses, based at specific sites, to be representative of a whole reach. Spatial variability is characteristic of river systems so replicate sites will increase our confidence that responses at particular sites apply to a whole reach. Second, statistical analysis of any contrast between reaches (e.g. between a reach with environmental flows and one without or between reaches with different types of environmental flows) will be based on replicate sites within each reach. Without some measures of site-to-site variability for each response variable or indicator, and also some measure of how that variability changes through time, it is impossible to determine *a priori* how many sites are required for each of the two types of inference described above. Additionally, with 16 different reaches, the number of sites will quickly become very large if there are many sites per reach (e.g. 5 sites per reach will be 80 in total), resulting in a very expensive and probably impractical (in terms of travel and other logistics) monitoring program. Therefore, our compromise is two key sites per reach but we also recommend additional sites for some response variables for those reaches that are part of specific contrasts.

Another significant decision is the choice of sites. Previous monitoring designs for assessing human activities in freshwater ecosystems have usually recognised the importance of multiple sites, but the criteria for selecting those sites has varied greatly between studies. The most common approach has been to choose sites that are judged to be “representative” of a reach but also that are accessible via a bridge, other road access or using a boat. There is no reason why accessible sites should necessarily be representative. Statistically, monitoring sites should be chosen at random from all the possible sites within a reach, helping to ensure that there is no inherent bias in site selection. However, we recognise that practical access is an overriding criterion in the choice of sites so our recommendations emphasise using sites that have been used in previous sampling, although the reasons why these sites were chosen for ISC or VWQMN sampling should be determined, if possible. Assuming random selection of sites is not possible, it is critical that the chosen sites are physically representative ("typical") of the reach in which they are located, i.e. they have typical channel morphology, riparian vegetation, and abundance of instream woody debris.

Two approaches may be used to address this issue. Formal descriptions of the in-channel and riparian morphology and vegetation ("habitat") at selected sites could be compared to descriptions of other randomly chosen sites within the reach (as a one-off sampling exercise if access is difficult). This would not be a trivial exercise so a simpler alternative is to use local knowledge and expertise, plus photographs and descriptions of the selected sites, to get agreement from stakeholders that the chosen sites are not unusual compared to the rest of the reach. SKM used a simplified version of this second approach to select sites for the Stressed Rivers and Bulk Entitlement studies.

Sites should include a "pool" and be centred on a 100 m section of river (although some sampling, such as for fish, may encompass up to 500 m of river). Sites should be at least 1 km apart and pools should be separated from pools at other sites by non-pool habitat (riffle or run). Most of the prescribed environmental flow requirements and predicted responses to environmental flows in the Wimmera and Glenelg Rivers have been based on field assessments conducted during the Stressed Rivers and Bulk Entitlement studies. Field sites used in those studies will therefore be priority monitoring sites (Key Sites) for testing specific hypotheses associated with environmental flow releases. We anticipate that all physical, hydrological and biological variables will be assessed at these sites, but most parameters will also need to be assessed at other sites within each reach to test spatial contrasts. Additional sites should be chosen to match VWQMN sites, then ISC sites. Water quality is an important response variable (especially salinity and DO in pools in summer) and most of these sites already have good water quality and flow data that can be compared against conditions after environmental flow releases. Some parameters will continue to be monitored at these sites as part of other ongoing programs and therefore the inclusion of these sites will reduce some of the cost of the environmental flow monitoring program. Finally, the EPA sites used for invertebrate sampling should be used if the above criteria do not provide five sites per reach, which is possible as some individual sites will be SKM, VWQMN, and ISC sites. These criteria will still not provide enough monitoring sites in some reaches and in those cases additional sites will be selected based on how representative they are of the particular reach, position within the reach and accessibility. Smaller tributaries may require fewer sites, but we recommend at least two sites per reach be chosen using the same criteria as above.

Rock stabilisation works and instream structures at gauging stations can create artificial flow and habitat characteristics that affect aquatic biota. Benthic macroinvertebrate, algal and macrophyte samples taken from these structures are unlikely to be representative of conditions throughout the reach and may bias the results of the monitoring program. This is a general problem for many stream monitoring programs, but is particularly pertinent in the Wimmera and Glenelg Rivers where rocks and concrete may have been introduced to streams that would normally just have sand, mud and wood substrates. We therefore recommend that all samples be taken at least 50 m downstream of road crossings, stream gauging stations and any apparent habitat modifications.

7.3 Specific hypotheses for individual reaches

The current condition of physical instream habitats and ecological communities varies between the selected reaches of the Wimmera and Glenelg systems. For example, reaches within the Grampians National Park have good instream habitat, with relatively intact riparian zones and diverse native aquatic fauna, but some middle and lower reaches of the Wimmera River have highly modified riparian zones, eroding channels and depauperate fish and invertebrate communities. The current degree of flow regulation also varies between reaches throughout these systems. These factors mean that the prescribed environmental flows are likely to have a substantial effect on flow regime and environmental condition in some reaches but preserve the status quo in other reaches.

This section describes some of the key flow regime changes in each reach and discusses some of the likely physical and biological responses to these flow changes.

7.3.1 Wimmera River upstream of Glenorchy

This section of the Wimmera River is not affected by the WMSDSS although some pumping licences permit abstractions directly from the river channel. Water savings from the Wimmera-Mallee Pipeline Project will not deliver environmental flows to this reach and therefore the flow regime is not expected to change. Specific hypotheses have not been developed for this reach.

7.3.2 Wimmera River: Glenorchy to Huddleston Weir

This section of the Wimmera River has steep sided banks, good in-channel habitat, a narrow but intact riparian zone, a relatively healthy macroinvertebrate community and a moderate native fish community, although the channel is more incised than it should be. Flow through this reach is currently ephemeral but winter flows are higher and less variable than would have naturally occurred. Flow transfers from Lake Lonsdale to Pine and Taylors Lakes cover the natural pool sequence and low benches through this reach for half of the year, which reduces the diversity of instream habitats available to macrophytes, fish and invertebrates. These constant flows are thought to favour exotic fish species such as carp and European perch and reduce the spawning success of native fish.

The environmental flows that have been prescribed for this reach should reinstate various natural flow components including summer low flows, summer freshes, a variable winter low flow and annual high flows.

The first stage of the monitoring program will be to determine whether the implemented environmental flows deliver these specific flow components. This can be done by visually inspecting water levels at monitoring sites during specific flow releases. Summer low flows should inundate bars between permanent pools to a depth of at least 13 cm during non-cease-to-flow periods (SKM, 2003a), which will provide riffle and macrophyte bed habitats. Summer freshes should wet woody debris, bars and low benches in the channel. The winter low flow should periodically inundate low benches and woody debris while maintaining riffle and pool habitats. High winter flows should wet most channel habitats, mobilise sediments and redistribute organic matter but controlled releases will be less than bankfull.

Summer low flows and freshes are likely to improve water quality in permanent pools. Summer low flows are likely to increase DO and reduce EC levels in permanent pools compared to cease-to-flow conditions, while summer freshes should temporarily increase DO and reduce EC levels compared to low flow periods but are unlikely to mix deep saline pools.

The recommended flow regime may lead to an increase in macroinvertebrate diversity with more riffle dwelling species, however given that previous studies have reported a healthy and diverse macroinvertebrate community in this reach, improvements due to environmental flows may be difficult to detect. High spring flows may enhance native fish spawning and recruitment, but barriers such as weirs will most likely prevent species such as golden perch from colonising this reach.

The introduction of a more variable flow regime would normally lead to an increase in the diversity and extent of riparian and aquatic vegetation. However, the steep banks in this channel mean that once the base of the channel is filled, flow fluctuations will only have minimal effect on the wetted perimeter and therefore we will be unlikely to see a large change in vegetation. Variable winter flows are however likely to reduce the rate of channel erosion.

7.3.3 Wimmera River: Huddleston Weir to the MacKenzie River confluence.

This section of the Wimmera River has a series of discontinuous pools separated by higher bars. The upper section of the reach has narrow steep sided banks, but there is also a shallower anabranching section. The riparian zone is in fair condition, but there is a good amount of woody debris in the channel and small stands of *Phragmites*. Under the current operating system, the reach immediately downstream of Huddleston Weir only receives overtopping flows. This means that all small and medium flows and some large flows have been lost from the system.

Environmental flows have been prescribed to return summer low flows, summer freshes, variable winter low flows and possibly spring freshes.

The summer low flows are expected to provide a trickle flow between all permanent pools and the summer freshes should wet low lying bars and woody debris within the channel. These summer flow components should increase the size and abundance of permanent pools throughout the reach, which will provide important refuges for native aquatic fauna. Winter low flows should inundate woody debris, bars, benches, undercuts and low-lying regions of the channel. Spring freshes should cover vegetated bars, benches and undercuts within the channel and wet anabranches and backwaters off the main channel for at least 14 days. Larger bankfull flows will not be provided by environmental flow releases.

Visual site inspections should be undertaken to determine whether flow releases provide the intended flow components and summer surveys can be done to determine whether the size and abundance of permanent pools has increased due to flow releases. Summer low flows and freshes are expected to improve water quality (increase DO and reduce EC) in permanent pools, but are unlikely to mix deep saline pools.

Spring freshes are likely to enhance the recruitment of native fish and this can be tested through fish surveys that specifically target juvenile fish in early summer. If the freshes do trigger spawning then we would only expect to see juveniles in years where spring freshes were provided. Fish surveys in reaches that do not receive spring freshes could also be used to test the effectiveness of freshes as a biological cue.

Previous studies have reported diverse macroinvertebrate communities in this reach of the Wimmera River, which may make it difficult to detect a large response of macroinvertebrates to environmental flows. However, improved water quality associated with summer flow releases may increase the abundance of sensitive macroinvertebrate taxa and this may result in an improved SIGNAL score over time.

This reach has a wider channel than the section upstream of Huddleston Weir and therefore the prescribed environmental flows are likely to lead to an increase in the diversity and extent of riparian and aquatic vegetation within the main channel. Phragmites is already abundant in this reach and monitoring will be important to determine whether environmental flows cause this species to become too abundant.

7.3.4 Wimmera River: MacKenzie River confluence to Lake Hindmarsh

This reach of the Wimmera River is characterised by large permanent pools in a wide, shallow channel, with poor riparian and instream vegetation dominated by *Phragmites*. Stock access and groundwater seepage have lead to bank erosion and eroded sediments have subsequently smothered many instream habitats. The reach has relatively diverse native and exotic fish populations, but the health of macroinvertebrate communities deteriorates downstream with few sensitive taxa found downstream of Lochiel. Regulation in upper reaches of the catchment has reduced the frequency and duration of small to medium flows and this combined with groundwater intrusions has resulted in very high salt levels in many of the permanent pools. Environmental flows have been prescribed to return summer low flows, summer freshes, winter low flows and spring freshes to the reach. High annual flows are also required through the reach but cannot be provided through environmental flows.

The summer low flows should provide a connecting flow between the permanent pools, and summer freshes should wet low lying bars and woody debris in the channel. These flows should increase the abundance and size of residual pools through summer but transmission losses (Anderson, Morrison, 1989e) mean that they are unlikely to have an effect downstream of Lochiel. Winter low flows should inundate critical in channel habitats such as woody debris, bars, benches and undercuts and should be deep enough to allow unimpeded fish movement along the length of the reach. Spring freshes should cover vegetated bars, benches and undercuts. Transmission losses mean that the effect of environmental winter low flows and spring freshes are likely to diminish downstream and are likely to have a reduced effect downstream of Lochiel.

The summer low flows are likely to prevent DO and EC levels from deteriorating to levels experienced during extended cease-to-flow periods and the summer freshes should periodically improve surface DO and EC levels, but are unlikely to flush deep saline pools.

Increases in aquatic habitat diversity and quality are likely to improve macroinvertebrate and fish abundance and/or diversity, however given that biotic communities are already in reasonable condition in the upper section of the reach, these changes may be difficult to detect. If environmental flows improve water quality downstream of Lochiel, then detectable increases in the abundance and diversity of sensitive macroinvertebrate taxa would be expected. The main purpose of spring freshes is to provide spawning and migration cues for native fish such as golden perch and therefore we would expect to see an increase in the abundance of juvenile native fish in summer samples following spring freshes.

The improved flow regime is likely to increase the diversity and extent of riparian and aquatic vegetation in the Wimmera channel. However the increase in medium sized flows without larger flow components that periodically disturb the substrate may result in an increase in the dominance of *Phragmites* and *Typha*, which would be considered a negative impact of flow releases. This may be an issue in the lower section of this reach where transmission losses are likely to reduce the size of flow peaks.

7.3.5 MacKenzie River: Mt Zero Channel to Distribution Heads

The upper section of this reach flows through the Grampians National Park. The river has good aquatic and riparian vegetation, diverse native fish populations and a healthy macroinvertebrate community. Some sections of the reach show bank erosion, and sediment from these banks has smothered habitats in a few places. Regulation has eliminated natural cease-to-flow events and reduced the magnitude, duration and frequency of high flow events. Environmental flows are prescribed to reinstate some cease-to-flow periods and some summer and winter freshes.

Summer cease-to-flow periods are likely to be short; they should eliminate flow between pools but not cause the streambed between pools to completely dry. Summer freshes should fill pools after the cease-to-flow events and wet low-lying habitats. Winter freshes should cover low benches, inundate emergent vegetation and move organic matter and sediment through the reach. These freshes are likely to increase the depth and width of pools and uncover other habitat elements at sites that have been smothered by mobile sediments. Water levels can be visually inspected to see if environmental flow releases achieve the desired flow regime and physical habitat changes can be monitored at sites with specific erosion problems.

The proposed environmental flows are primarily aimed at preserving the current health of this reach, and therefore we would not expect substantial changes to biota or water quality. The most likely biological response would be an increase in native fish recruitment after winter and spring freshes.

7.3.6 MacKenzie River downstream of Distribution Heads

The channel in this reach has steep banks with good riparian vegetation and good instream habitat. Flow would have been naturally ephemeral, but current regulation diverts virtually all flows at Distribution Heads, which means that flow through this reach now relies on local catchment run-off. Natural high flow events still occur, but summer and winter low flows and medium sized summer freshes have been lost. Previous studies have at times reported some native fish and moderately healthy macroinvertebrate communities through this reach, but abundance and diversity is limited by the lack of water. Prescribed environmental flows are intended to reduce the duration of the cease-to-flow period and provide low flows and freshes throughout the year.

The most noticeable effect of environmental flows will be the return of water to this reach for most of the year. Summer low flows should provide connecting flows between pools and increase the number and size of permanent pools throughout the reach. Summer freshes should replenish pools after cease-to-flow periods and wet low-lying habitats. Winter low flows should wet all channel habitats without breaking out onto the benches and winter freshes should inundate benches and emergent vegetation. Flows should be visually inspected during release periods to determine whether the prescribed flow components have been provided.

The increase in the abundance and size of permanent pools in this reach is likely to lead to an increase in the abundance and diversity of macroinvertebrate and fish populations although artificial structures in the stream may prevent colonisation from healthy upstream fish populations. The winter and spring freshes are intended to trigger fish spawning events. This is unlikely to have much effect on fish species that currently occur in this reach. However, increased flows and freshes are likely to facilitate fish migration from the Wimmera River and freshes may then allow these new species to breed and becomes established within the MacKenzie River. Successful spawning and recruitment of these new species is unlikely to occur for several years and may be a longer term monitoring objective.

7.3.7 Mt William Creek: Lake Lonsdale to the Wimmera River

Land clearing and stock access have contributed to bank erosion and a poor riparian condition through this reach. This erosion has delivered large sediment loads to the river, which have filled pools and turned long sections of the reach into homogeneous runs. Current regulation provides permanent flow between Lake Lonsdale and the Main Outlet Channel, but flows downstream of the channel are less than would naturally occur. However, good fish and macrophyte communities in Mt William Creek downstream of the Main Outlet Channel suggest that biota are not severely affected by the current flow regime. Environmental flows are prescribed to reduce the cease-to-flow period downstream of the Main Outlet Channel and provide more flow during winter.

No summer low flows are prescribed, but summer freshes are recommended to maintain the quantity and quality of permanent pools. Winter minimum flows should provide continuous flow that will allow fish movement throughout the reach and winter freshes should wet the channel benches and vegetated backwaters and mobilise organic matter and sediment.

The most noticeable effect of environmental flow releases is likely to be an increase in the size and number of permanent pools in the reach and changes to water levels during the natural wet seasons. Larger flows may move some organic matter through the channel and deposit sediments on channel bars and benches, but they are unlikely to scour pools. Freshes have the potential to improve riparian and in channel vegetation, but no detectable effects are likely unless stock access is also controlled. The relatively healthy condition of aquatic biological communities in this reach mean that any biological improvements will be difficult to detect, but summer fish surveys should indicate whether spring and winter freshes contribute to native fish recruitment.

7.3.8 Burnt Creek: Distribution Heads to Toolondo Channel

This section of Burnt Creek has a small channel with a good riparian zone, however uniform stream flows have reduced the amount of instream habitat and vegetation. Previous studies have reported a healthy native fish population in this reach, but macroinvertebrate communities have not been sampled. Flow through this reach would have naturally been ephemeral, but regulation has resulted in constant summer low flows and elevated winter low flows. The main environmental flow recommendation is to introduce a long summer cease-to-flow period and more variable winter flows.

Burnt Creek should contract to a series of permanent pools during the cease-to-flow period. Winter low flows will provide continuous flow through the reach, replenish pools and increase the likelihood that pools will persist through summer. Winter freshes should inundate all habitats in the main channel and wet vegetation stands in backwaters and anabranches. Large bankfull flows are needed to move sediments and redistribute larger material in the channel but these are unlikely to be provided by environmental flow releases.

Visual site inspections should be undertaken to determine whether flow releases provide the desired flow components to the reach. Visual inspections will be able to determine whether the system contracts to a series of permanent pools that are sustained by winter flow releases, and that winter freshes wet backwaters and anabranches. The more variable flow should increase the diversity and extent of riparian and in-channel vegetation. Cease-to-flow periods may reduce the abundance of exotic fish species but should not impact on native species that are adapted to ephemeral conditions. Winter freshes may assist the recruitment of native fish species that currently occur through this reach, but instream barriers are likely to prevent other native species from moving into the reach. As such, there is unlikely to be much change to the native fish community. The introduction of a more natural flow regime is likely to support a healthy macroinvertebrate community, but since little is known about the current macroinvertebrate community it is difficult to predict whether any changes are likely. There is little information about water quality in this reach and so monitoring will be needed to ensure that DO and EC levels do not deteriorate appreciably in remnant pools.

7.3.9 Burnt Creek: Toolondo Channel to the Wimmera River

The Burnt Creek channel is in good condition and has a good riparian zone, but there is no flow except in very wet conditions. The lack of water means that a high organic load has accumulated in the channel and this could lead to water quality problems (low DO) after the first flush. Current conditions do not sustain aquatic communities, some fish have been recorded in this reach but they most likely colonised pools from upstream habitats and would have died when the pools dried up. Environmental flows are prescribed to provide some reliable winter flows and to ensure refuge pools persist throughout summer.

Winter low flows are expected to provide continuous flow through the reach and ensure that permanent pools persist through summer. Winter freshes should fill the channel enough to allow fish movement between pools and to wet vegetation stands in backwaters and anabranches. Larger bankfull flows will probably not be provided by environmental flows.

Monitoring through this reach should focus on the persistence of permanent pools and water levels during spring or winter freshes. Since there are no permanent invertebrate and fish populations in this reach we would expect the introduction of environmental flows to increase the abundance and diversity of both communities. These biological changes will be very easy to detect. Winter and spring freshes may enhance recruitment of mountain galaxias and other native fish, but this will depend on whether individuals can colonise this reach from populations upstream of Toolondo Channel or the Wimmera River. The flow regimes would however be expected to increase the diversity and extent of riparian and aquatic vegetation in the main creek channel.

7.3.10 Glenelg River upstream of Rocklands Reservoir

Moora Moora Reservoir is the main flow regulating structure in the Upper Glenelg. However, it is only a small storage with a capacity of 6,290 ML. Water savings associated with the Wimmera Mallee Pipeline project may result in this reservoir being decommissioned but this is considered to be a relatively low priority. The decommissioning of Moora Moora Reservoir would have negligible effect on flow in the Upper Glenelg River and therefore no specific hypotheses are described for this reach.

7.3.11 Glenelg River: Rocklands Reservoir to the Chetwynd River confluence.

The river channel through this reach has a combination of pool, riffle, run and glide habitats with narrow alluvial flats along the stream margins. Riparian vegetation through this reach varies from good to poor condition, but the aquatic vegetation is generally diverse and abundant. The reach supports a variety of native and exotic fish species, including some native species of high conservation value and macroinvertebrate communities in the reach are considered to be moderately healthy. Flow regulation has substantially reduced the cease-to-flow period, summer and spring freshes and overall flow variability. Water quality throughout the reach is generally poor and erosion has contributed high sediment loads that smother many instream habitats. Flow regulation is thought to favour exotic fish species over native species by removing spawning cues and natural cease-to-flow events. The increased sediment loads and reduced overall flow are also considered to have lead to *Phragmites* and *Typha* encroaching on the main river channel. All flow through this reach is currently determined by controlled releases from Rocklands Reservoir but the recommendation is to increase the magnitude and frequency of summer and spring freshes and winter low flows. Summer low flows will remain at the current level, and cease-to-flow periods have not been recommended because of the likely impacts on water quality.

Summer freshes should wet most bars through this reach and reduce the stratification of saline pools. Winter low flows should provide continuous flow through the reach and wet low lying bars, snags and channel margins with emergent vegetation. Spring freshes should wet most of the channel. Visual inspections should be conducted during specific flow releases to determine whether they reach the expected water levels and therefore provide the required flow components.

Water quality issues are of greatest concern during summer. The only recommended change to the current summer flow regime is the introduction of summer freshes. These freshes are expected to reduce stratification in deep saline pools, therefore we would expect to see a temporary reduction in EC and an increase in DO in these pools after the freshes.

Bank and sheet erosion have contributed large sediment loads to this reach of the Glenelg River, which has smothered important instream habitats. Natural flow conditions would have gradually moved this sediment downstream, but constant low flows have helped to consolidate this sediment and it has now been colonised by emergent macrophytes and some riparian species. The proposed environmental flow regime is likely to mobilise these sediments and change their distribution. Small to medium flows are likely to cause some pool infilling (which may be regarded as a negative effect of environmental flow releases) but winter high flows are expected to scour sediment out of some pools. Larger flows may also reduce the extent of *Phragmites* and *Typha* stands that have encroached towards the middle of the Glenelg River channel under the current flow conditions. If environmental flows only deliver low flow components to the Glenelg River then we would expect to see a reduction in the length, width and depth of pool habitats throughout the reach, however if recommended high flows are also introduced then scouring effects may increase the dimension of instream pools. The best way to assess these physical effects would be to compare the dimension of specific pools before and after individual flow releases. Such monitoring would only need to be done once for each flow component and longer term monitoring can be used to assess net changes associated with the prescribed flow regime. Vegetation changes are also likely to vary with different flow components. Large winter and spring flows are likely to reduce the extent of emergent vegetation in the centre of the main channel, but sustained low flows may enhance encroachment. Vegetation changes are likely to be relatively long term and therefore reductions in the extent of vegetation are only likely to be evident after several years of high flow releases.

Previous studies have correlated changes to macroinvertebrate communities with environmental flow releases in this reach of the Glenelg River (Mitchell, 2001; Mitchell, *et al.*, 2002). Proposed summer freshes should improve water quality in permanent pools and proposed winter flows should increase the quantity and diversity of instream habitats. As a result we may expect to see an increase in sensitive taxa such as molluscs, caddisfly and mayfly larvae and some species that inhabit riffle/run habitats and submerged snags.

Without the introduction of a cease-to-flow period there is unlikely to be much change to the exotic fish community, but the introduction of spring freshes and high flows is likely to increase native fish recruitment. This can best be tested by comparing the relative abundance of juvenile native fish in summers after environmental spring freshes, against data from years without spring freshes.

7.3.12 Glenelg River: Chetwynd River to Wannon River

Inflows from unregulated tributaries reduce the impact of Rocklands Reservoir on flow downstream of the Chetwynd River. Erosion and associated sand slugs that smother aquatic habitats are the main impacts in this reach of the Glenelg River. Over time, *Phragmites* and *Typha* have colonised these sandbars, which has constricted the main river channel. Flow recommendations for this reach are the same as the reach between Rocklands Reservoir and the Chetwynd River. However, inputs from unregulated tributaries already provide many of the natural flow components and transmission losses in the upstream reach mean that small to medium releases from Rocklands Reservoir will have little or no effect through this reach.

Summer low flows are recommended to connect pools, and summer freshes are recommended to inundate low-lying habitats and improve water quality in pools. Winter low flows are intended to maintain flow over snags, channel bars and benches, and spring freshes should wet most of the channel. The main monitoring focus for this reach should be to determine whether environmental flow releases from Rocklands Reservoir affect flow downstream of the Chetwynd River. If environmental flow releases have no discernible effect on water levels in this reach then there is little point trying to test for geomorphological or biological responses. If flow changes are detected, then many of the hypotheses described for the Rocklands Reservoir to Chetwynd River reach can also be tested here.

7.3.13 Glenelg River: Wannon River to the Tidal Extent

Flow releases from Rocklands Reservoir are unlikely to have an effect this far downstream and so no hypotheses are described for this reach. However temporal changes to water quality and biota in this reach may provide a useful comparison for reaches that do receive altered flow regimes.

7.3.14 Wannon River

The upper reaches of the Wannon River are characterised by cobble streams with natural riffle-pool sequences. The channel is structurally intact and has an intact riparian zone but flow through the First and Second Wannon Creeks is highly regulated. These streams have natural summer flows but most of the winter flow is diverted. Environmental flow recommendations include the provision of winter low flows and winter freshes.

The winter low flow should provide continuous flow through the reach, and maintain riffle and pool habitats for fish and macroinvertebrates. Winter freshes are expected to wet wider riffle and channel habitats and provide breeding and migration cues for native fish.

No hydraulic models have been developed for the upper Wannon River, but water levels through this reach should be visually inspected to determine whether released flows cover riffle habitats and provide connecting flows. Environmental flows are likely to increase the abundance and diversity of aquatic habitats and this is likely to cause an increase in fish and macroinvertebrate diversity. In particular we would expect to see an increase in the abundance of species that inhabit riffles and other fast flowing habitats and that spawn or migrate in response to larger spring and winter flows.

7.4 Contrasts between individual reaches

Similar flow components have been prescribed for most reaches within the Wimmera and Glenelg systems. Recommended flows are based on the ecological and geomorphological requirements of the system and were developed independently of the capacity of the Wimmera-Mallee Pipeline and WSDS to deliver particular flows. Water savings from the Wimmera-Mallee Pipeline are unlikely to deliver very large flows to any parts of the catchment and medium sized flows such as spring freshes may only be delivered to certain reaches. Some reaches may not receive any environmental flows and releases may vary each year in other reaches.

Variation in the delivery of specific environmental flow components between reaches may be used to test ecological or geomorphological responses to specific flow components. For example, native fish recruitment can be compared between reaches that do and do not receive spring freshes. For this contrast, we would predict that native fish recruitment would be higher in the reach that received spring freshes than the reach that did not receive them. Contrasts between multiple reaches that do and do not receive particular flow components will provide more powerful tests. However, it is important that the reaches being compared are physically and ecologically similar except for flow and alternative explanations for any observed differences need to be considered. In the example given above, the potential impact of instream barriers on fish migration needs to be discounted before differences in native fish recruitment can be attributed to differences in flow.

In order to increase the statistical power of contrasts between specific reaches it may be necessary to collect data from more than two sites in each reach, and additional sites have been listed in Table 7-2. In most cases contrasts between specific reaches will only be suitable for testing short-term responses to environmental flow components. However, any reaches that are consistently deprived of specific flow components may be used to compare some long-term responses to those flow components in other reaches.

At this stage, no clear decision has been made about which flow components are to be delivered to which particular reaches. Therefore we cannot specify particular reaches or flow components to be tested through this spatial contrast. Once the schedule for environmental flow releases is more clearly defined, staff from the Wimmera and Glenelg Hopkins CMAs can decide which hypotheses they wish to test and then monitor the appropriate response variables.

The details of the reaches and sites are provided in Table 7-2. A more detailed outline of parameters to measure at each site and sampling frequency is presented in Appendix A.

- **Table 7-2 Recommended monitoring sites for the reaches in the Wimmera and Glenelg catchments. Key reaches are shown in bold. The table includes a description of previous studies that have used each site and gives a grid reference location.**

Study Reach	Recommended monitoring sites	Previous data from this site	Easting	Northing
Wimmera Catchment				
Upper Wimmera (45 km) Potential contrast with Glenorchy to Huddleston reach	**Glynwylln**	SKM cross section, VWQMN site 415206	665591	5907934
	Cambells Bridge (Stawell Donald Rd)	EPA site IIM	658900	5911800
	Joel Joel Bridge	EPA site IIL	677768	5901563
	Glenorchy (Stawell – Warracknabeal Rd)	Mitchell & Lind study site	647500	5913500
	Hunts Rd (off Glenorchy – Campbells Bridge Rd)	No Data	653000	5912850
Glenorchy Weir to Huddleston Weir (12 km) Potential contrast to Upper Wimmera reach	**Daves Lane**	SKM cross section	640000	5917000
	Glenorchy Weir tail gauge	VWQMN site 415201 & EPA site IHJ	646099	5913841
	Ledcourt Rd	No Data	644450	5915300
	Companys Bridge	No Data	639000	5918200
	U/S Huddleston Weir	No Data	636000	5920900
Huddleston Weir to Lake Taylor Outlet (26 km)	**D/S Huddleston Weir**	SKM cross section	636200	5920800
	Halls Island	SKM cross section	631081	5929996
	Faux's Bridge	EPA site IHB	634460	5924680
	No other accessible sites in this reach			
Lake Taylor Outlet to MacKenzie River (36 km)	**Gross' Bridge**	SKM cross section	618500	5935100
	Horsham Rifle Range	SKM cross section	602148	5933099
	Wimmera River at Horsham	VWQMN site 415200	602672	5933339
	1.5 km South of Monument upstream of Horsham	EPA site IHC (reference site including airlift)	610400	5937900
	Dooens Swamp	Water EcoScience invertebrate and fish data.	612200	5939650

Study Reach	Recommended monitoring sites	Previous data from this site	Easting	Northing
Wimmera River: MacKenzie River to Lake Hindmarsh (106 km) Note most of the recommended monitoring sites are upstream of Lochiel since only high flows are likely to have an effect downstream of this point. Sites denoted by * are downstream of Lochiel and should only be used to monitor the effect of large flow releases.	**O'Brees Crossing**	SKM cross section	586900	5937850
	Horseshoe Bend	SKM cross section & EPA site IJF reference site	591000	5959800
	Lochiel Railway Bridge	VWQMN site 415246	586971	5970124
	Kenny's Ford	EPA site IHI airlift & Mitchell and Lind site	599300	5931100
	D/S Dimboola Weir	EPA site IHK airlift and reference site	590193	5966247
	Antwerp *	EPA Site IIV, Anderson & Morison	591543	5982731
	Tarranyurk * (Tarranyark West Rd)	Mitchell & Lind site, Anderson & Morrison site.	591000	5991950
MacKenzie River: Mount Zero Channel to Distribution Heads (15.5 km) *Could possibly use EPA reference site at Zumsteins as upstream control or reference.*	**Wartook: Grampians – Mt Victory Rd.**	SKM cross section	619100	5900300
	Tatlocks Bridge (Brimpaen – Laharum Rd)	EPA site IIP	617171	5904407
MacKenzie River: Distribution Heads to Toolondo Channel (12 km)	**Grahams Bridge Road**	EPA site IIJ	609800	5910150
	Hickeys Road	No Data	610250	5915250
MacKenzie River: Toolondo Channel to the Wimmera River (23 km)	**Upstream of Wonwandah Rd**	SKM cross section	605500	5916400
	Henty Highway at MacKenzie Creek	VWQMN site 415251 & EPA site IHH reference site	605255	5925541
Mount William Creek: Downstream of Lake Lonsdale (49 km)	**Western Hwy – Dadswells Bridge**	SKM cross section & EPA site IHV	634400	5913300
	Lake Lonsdale tail gauge	VWQMN site 415203	640532	5900618

Study Reach	Recommended monitoring sites	Previous data from this site	Easting	Northing
	Glenorchy – Roses Gap Rd Morgans Bridge	EPA site IHF reference site	634400	5909800
	Horsham - Wal Wal Rd	No data	630000	5924900
	Crutes Rd	No data	632150	5918100
Burnt Creek: Between Distribution Heads and Toolondo Channel (18.5 km)	**US Laharum Rd WonWondah East**	SKM cross section	609850	5917352
	Franciscos Rd	No data	612100	5913800
Burnt Creek: Downstream of Toolondo Channel (24 km)	**DS Laharum WonWondah Rd**	SKM cross section	612079	5918855
	Reynolds Rd	No data	610650	5956800
	Western Hwy	No data	611400	5930700
Glenelg River: Upstream Rocklands Reservoir	**Big Cord**	SKM Cross section, VWQMN site 238231 & EPA site JIH	621127	5869070
	Red Hill Road	EPA site JII (this site unlikely to be affected by abstraction but may be used as a reference)	617363	5865824
	Henty Hwy	No data	605000	5892000
	Glenisla Crossing Rd	No data	611000	5887000
	Syphon Rd	No data	618000	5882000
Glenelg River: Rocklands Reservoir Dam Wall to Chetwynd River (113.5 km) * Denotes sites upstream of five mile outlet, all other sites are downstream of twelve mile outlet. These sites can be used to compare flow releases from different outlets.	Fulham Bridge	VWQMN site 238224, EPA reference site JIJ, Mitchell and Lind	575482	5888135
	Pine Hut Hole	SKM cross section, Mitchell & Lind	579638	5889293
	Dick Roberts Property	SKM cross section	580832	5883370
	Harrow	SKM site at pump station, EPA site JJM	552242	5885894
	Mooree - Connewirrecoo Rd	EPA site JIX	544300	5880600

Study Reach	Recommended monitoring sites	Previous data from this site	Easting	Northing
	Rocklands Reservoir *	VWQMN site 238205	584262	5878066
	Balmoral * (Rocklands Road)	Mitchell and Lind	570500	5877200
	Five Mile outfall *	SKM cross section	579638	5889293
Glenelg River: Chetwynd River to Wannon River (82 km)	**Burkes Bridge (Casterton – Edenhope Rd)**	SKM cross section, EPA site JJN, Mitchell and Lind	534226	5881842
	200m us Warrock Rd Bridge	SKM cross section	523995	5856182
	Section Road	SKM cross section	534192	5846549
	Dergholm – Chetwynd Rd	EPA reference site JIG	521360	5864390
	Casterton – Naracoorte Rd	EPA site JIR	535710	5840720
Glenelg River: Wannon River to Dartmoor (90 km: tidal extent)	**Sandford (ds Bahgallah Rd Bridge)**	SKM cross section, VWQMN site 238202, EPA site JIP	537065	5836248
	Dartmoor (streamside reserve us Greenham Rd)	SKM cross section, VWQMN site 238206, EPA reference site JIE	524607	5801900
	Killara (Casterton – Dartmoor Rd)	EPA reference site JIC	527660	5830888
	Myaring – Pieracle Rd	No Data	520000	5819000
	School Rd Wilkin	No Data	522000	5825000
Wannon River: Upper reaches	**First Wannon Creek downstream of weir**	SKM assessment site but no cross section data	636400	5869700
	Second Wannon Creek downstream of weir	SKM assessment site but no cross section data	636300	5868700
	Wannon River at Jimmy Creek	VWQMN site 238207	632819	5863011

7.5 Variables

The selection of ecological response variables is a fundamental component of any monitoring program, and assessing responses to environmental flows is no exception. Downes *et al.* (2002) reviewed the criteria for selecting response variables when monitoring effects of human impacts in flowing waters and summarised the pros and cons of particular biotic groups. They emphasised three main criteria for selecting variables:

- There is an established causal link between the variable and the stressor or restoration activity. In the case of environmental flows, this means that we would select variables that we expect to respond to the types of flow change being implemented. However, this can only be done once flows have been assessed to confirm that different flow components have been delivered.
- The variables are of socio-economic or ecological importance. This may include variables that are associated with the particular objectives of the environmental flow regime, as specified in the relevant environmental flow reports, or variables that have a high public profile, such as native fish.
- The variables are efficient (cost-effective) to sample. We should choose variables that are relatively easy to sample and have low variability between sites and through time. If our variables are particular species of plants or animals, then they need to be abundant enough not to be affected by repeated sampling. Finally, we should look for indicator variables that provide a broader assessment of ecosystem change (e.g. river health indices).

It should be noted that these criteria can be in conflict for some variables, e.g. a high profile native fish species may be too rare for repeated or reliable sampling. Also, our understanding of causal links between biota and ecological processes and flow change is limited (see (Lloyd, *et al.*, 2003) so choosing variables based on the first criterion is often based on experience and conceptual models, rather than empirical evidence from a particular river.

We agree with the criteria proposed by Downes *et al.* (2002) but also add two additional ones, the availability of baseline data and links to environmental flow objectives. The monitoring of the Wimmera and Glenelg Rivers cannot be a straightforward “before versus after” comparison (environmental flows have already started), so existing data for particular variables are important. The environmental objectives set for the environmental flows (SKM, 2002a; b; 2003a) must also influence which variables to monitor.

We have reviewed the variables that could be used for assessing responses to environmental flows in the Wimmera and Glenelg Rivers and assigned them, based on the criteria above, into one of three categories (see also (Reid, Brooks, 1998) – key variables that should be monitored, second tier variables that would be useful but don’t meet one or more of the criteria above, and variables that are not suitable for monitoring effects of environmental flows in the Wimmera and Glenelg Rivers. The proposed monitoring program should primarily focus on measuring key variables. Second tier variables can be measured if time and resources permit, but if not they may be incorporated into complimentary research projects that assess ecological responses to flow in the Wimmera and Glenelg Rivers. We summarise the methods and sampling frequency in Table 7.2

7.5.1 Water quality

Key variables would be dissolved oxygen (DO, especially in pools), conductivity (EC, as a measure of salinity), water temperature and turbidity. Some of the variables are clearly linked to flow, e.g. DO can get very low in pools during summer due to lack of flow, and low DO and high salinity are two problems the environmental flows in both rivers are designed to address. These variables are also simple to measure using a portable meter, are usually recorded as part of routine water quality monitoring, and there is a good baseline dataset for some sites on these rivers through the Victorian Water Quality Monitoring Network. It is important to recognise that water quality can vary between pool and run habitats within the same river reach. Many VWQMN sites only have data for run habitats, but an environmental flows monitoring program will need to focus on measuring specified parameters in pools.

Salinity is an important issue, especially in the Wimmera catchment. Environmental flows are not likely to have a large effect on salt transport loads within the Wimmera or Glenelg systems, but they are likely to have a substantial effect on water quality in permanent pools. As a result, the environmental flows monitoring program should focus on EC levels in pools rather than runs at low and zero flow and changes in EC levels with depth.

Second tier variables would be nutrients such as nitrogen and phosphorous. These do not have simple causal links to flow change, and are probably more affected by the source of water (i.e. which channel or distribution point the water comes from). In addition, they need to be analysed in the laboratory, which will make them expensive to measure. However, nutrient levels are often included in assessments of water quality in rivers and streams and changes in nutrient levels will reflect broader catchment activities such as land-use.

One possible variable that has been rejected is suspended solids, because it is expensive to determine and a much more cost-effective substitute (turbidity) is available.

Water quality varies over a range of temporal scales and therefore selected parameters will need to be monitored monthly throughout the program, with dates matching those used for the VWQMN sampling. Ideally, sampling would be standardised to the middle of the day (e.g. 11am to 3pm), because some variables will depend on temperature and incident light (e.g. surface DO). We recognise that it may not be possible to cover all the sites if constrained to such a narrow time window. If so, then it is important that each site is sampled at the same time of the day each month.

In areas where industrial or agricultural discharges are likely to affect water quality, it is often recommended that samples be collected at random times and days throughout the month to increase the likelihood that regular discharges are detected. This is not likely to be a major concern in the Wimmera and Glenelg systems and therefore the water quality sampling schedule should coincide with the ongoing VWQMN program. However, water quality variables will change depending on flow state so additional sampling before and after an environmental flow “event” (e.g. a spring or summer fresh) should be used to assess short-term changes in DO, salinity and turbidity in pools in response to environmental flows. These before and after sampling events should be at comparable low flows, as most interest will be in assessing effects of summer events.

Within-site replication is important as water quality might vary on small spatial scales. We suggest that at least three locations be sampled at each site – these might be three separate pools or three measurements within one large pool depending on the site. We also recommend that one surface and one bottom measurement be taken at each location (with depth recorded) to assess how flow releases affect water quality at different depths. Improvements to surface water quality but not at depth have important implications for the quality and availability of fish habitat.

To do all sites, we expect that two people will be able to sample all Wimmera catchment sites over three days and all Glenelg catchment sites over two days. One way to overcome the time and workload issue would be to install data loggers that could continuously monitor salinity, dissolved oxygen, temperature and flow. This is likely to be expensive but may be a worthwhile investment at a small number of specific sites. The RWC operated continuous salinity data loggers in pools at Lower Norton and Big Bend in the Wimmera River between 1992 and 1995 and manually measured salinity at various depths in three other pools at Lower Norton, Polkemmet and Tarranyurk (Western, 1994). This is very good baseline data from an area of the Wimmera where salt intrusions are a particular problem and any new data loggers should be installed in at least some of these pools.

7.5.2 Physical components of channel

Flow regulation affects the movement of sediment through the system in two ways. First, by reduced entrainment and transport of sediment due to lower flow energy, and second, artificial structures prevent the transport of flows to downstream habitats. Both are issues in the Wimmera and Glenelg rivers, but environmental flows only address the first issue.

Bankfull and overbank flows drive most channel-forming processes. These flows have not been substantially affected by regulation and will not be addressed by environmental flow releases; therefore major channel-forming processes will not be considered in this monitoring program. The main geomorphological effect of regulation in the Wimmera River is the consolidation of substrate material and vegetation encroachment within the channel. The reduction in small to medium flows means that many channel habitats are not wetted as frequently as would have occurred naturally. Frequent wetting prevents the consolidation of sediment within the channel, which means that relatively low energy flows are then able to shift bed material. In the absence of frequent wetting, riparian vegetation such as *Phragmites* and *Typha* can encroach further into the main river channel and colonise sediment bars and benches. This vegetation impedes flow and further restricts sediment transport. Low flow releases that were not accompanied by high flows have been associated with the expansion of *Phragmites* and *Typha* in the South Australian River Torrens (I Rutherfurd pers.comm.). One of the environmental objectives for these catchments is to manage vegetation encroachment within river channels especially in the Glenelg River and Upper Wimmera. The Wimmera CMA have received anecdotal information that previous environmental flow releases have actually lead to an increase in *Phragmites* and *Typha* growth in the lower Wimmera River, and this monitoring program may be important for objectively assessing these vegetation changes. Some of the riparian taxa specified in the environmental flow objectives for the Wimmera and Glenelg Rivers may respond to root wetting from bankfull flows, but most of these plants require overbank flows. The prescribed environmental flows are unlikely to have much affect on riparian community composition and therefore they will not be included in this monitoring program.

The Glenelg River has a more mobile bed than the Wimmera River and sand deposition is a major issue throughout the catchment. Sand has accumulated in the Glenelg as a result of increased erosion associated with land clearing practices. Most of the sand in the Glenelg River was deposited in the 1946 floods and large sediment bars have developed near many tributary junctions (Rutherfurd, Budahazy, 1996). The loss of small to medium sized flow components has meant that much of this sand is now consolidated within the river channel. Recommended environmental flows may have some effect on the small-scale movement of bed material in the Glenelg River, but active sand extraction (which is currently being done) and large natural floods are likely to have a greater effect.

Environmental flows that remobilise sediment may also have a detrimental effect on physical habitats, particularly in the Glenelg River downstream of Rocklands Reservoir. Natural pools in the Wimmera and Glenelg Rivers are formed by scour during high flow events, but smaller flows wash sediments into the pools, which causes infilling. In undisturbed systems, pool scour and infilling would be dynamic, but regulation and high sediment loads have disrupted this process. Proposed environmental flows are likely to restore some small to medium flow events but will not affect larger flows. Environmental flows are likely to increase the rate of pool infilling, but have little effect on pool scour, which may ultimately result in a loss of important pool habitats. Infilling will occur from the upstream end of each pool and can be monitored by placing a stake in the streambed at the top of a pool and measuring longitudinal sand migration into the pools over time. Photo points and longitudinal profiles of the streambed or repeated surveys of individual pool dimensions over time can also be used to record pool infilling and other physical changes over time.

Geomorphological changes occur over long and often unpredictable time scales (Brizga, 1998) and small changes that may occur as a result of environmental flow releases can also be overshadowed by changes associated with larger floods. We therefore recommend that this monitoring program should focus on short term geomorphological changes associated with specific flow events. Long-term physical changes to the channel shape and vegetation extent will also be useful, but it will be difficult to directly attribute any changes to environmental flows.

Intensive monitoring before and after specific environmental flow releases could highlight changes to pool dimensions, sediment deposition on channel bars or benches and the redistribution of woody debris and other habitat elements within the stream as outlined in the specific hypotheses described earlier. These assessments only need to be done at one or two sites in each study reach. Ideally, these sites would comprise a mix of sites with existing cross section data and sites where pool infilling, erosion and in-channel debris are particular issues. CMA staff and other people with a detailed knowledge of the catchment are probably in the best position to select which sites with specific geomorphological issues should be monitored. These assessments will be testing specific hypotheses relating to particular flow events and may be rather time intensive. However, they only need to be done once for any particular flow component. This should be sufficient to determine whether the delivered flow component has had the intended effect. Needless to say that only hypotheses relating to flow components that are actually released need to be tested. Some of the main geomorphological changes such as redistributing woody debris and formation of new benches may only result from large flows, which may not be provided by controlled environmental flow releases in these systems. Large natural flows are likely to affect channel forming processes, but geomorphological parameters that respond to flows other than active environmental flow releases will probably be second tier variables rather than key parameters.

The short term monitoring described above relates to changes associated with specific flow components. Long term changes due to these individual components and the overall implementation of a more natural flow regime should also be assessed. Long term changes to channel shape and vegetation encroachment within the channel will be best assessed by repeated surveys of fixed cross sections and longitudinal surveys that record vegetation distribution limits. As with short term geomorphological responses, these factors only need to be assessed at one or two sites per reach and where possible the same sites should be used for both long and short term monitoring. Table 7.1 indicates which sites should be used for geomorphological and vegetation assessments. All of the sites that SKM used for the Stressed Rivers and Bulk Entitlement reports had six cross sections and longitudinal surveys. We recommend that these cross sections should be located and used for this monitoring program, as they will provide an indication of conditions prior to any flow releases. The same number of cross sections should be established at nominated sites in reaches that do not have existing cross section data. Repeated surveys every three to five years should be sufficient to detect long term changes, but it must be recognised that any changes will not necessarily be attributed directly to environmental flow releases. *Phragmites* and *Typha* die-back in winter and have different growth phases at other times of the year. Therefore surveys to assess vegetation encroachment need to be conducted in the same season in each sampling year. We recommend that sampling be avoided in winter, and would probably be best done in late summer when flower heads are present.

7.5.3 Hydrology

Many of the hydrological predictions for particular environmental flow releases are based on one dimensional modelling at a limited number of cross sections or extrapolations from rating curves at a single gauge station. These models have been used to determine the discharge that is required in each reach to provide the required flow components. For example a minimum winter flow of 60 ML/day is prescribed to inundate snags and bars and provide longitudinal connectivity for fish migration in the Wimmera River between Huddleston Weir and the MacKenzie River confluence. The first stage of the monitoring program (other than collection and analysis of pre-release data) should therefore be to measure discharge and water levels at various sites during flow releases to determine whether the environmental flow releases inundate the specified habitats in each reach. It will also be important to determine how long specific habitats remain inundated.

Most of the prescribed flows and predicted hydrological responses are based on cross section and longitudinal section surveys that SKM conducted at various sites in the Wimmera and Glenelg catchments for the Stressed Rivers and Bulk Entitlement reports. These should be used as key sites for the environmental flows monitoring program. Water depth at established cross sections, discharge, wetted perimeter and the level of habitat inundation should be measured at each of these sites during different flow releases to determine whether the delivered flows have the predicted hydrological effect. In many cases visual inspections may provide adequate yes or no tests of reach specific hypotheses described in section 7.3. Water levels during flow releases should also be inspected at other sites within each reach to track flows down the system and determine whether transmission losses prevent the delivery of specific flow components throughout each reach.

The Wimmera CMA and Glenelg Hopkins CMA may wish to conduct detailed hydraulic assessments at sites that have important physical habitats or that have particular geomorphological and ecological assets or impacts. These assessments would be the same as those prescribed for the key sites described above, but should not replace monitoring at those key sites. Additional sites would need to be nominated and or selected by CMA staff, the local community and other people with a detailed working knowledge of the Wimmera and Glenelg systems.

In some reaches more detailed studies may be required to quantify transmission losses and lag times associated with specific flow releases. SKM (SKM, 2002d) have already done this for small flow releases from Rocklands Reservoir into the Glenelg River. They compared transmission losses in five river sections (shorter than the key reaches described in Chapter 5 and Table 7.1) between Rocklands Reservoir and Burkes Bridge and tested the amount of water that needs to be released from Rocklands, Five Mile and Twelve Mile Outfall to achieve at least 11 ML/d at Harrow. They used permanent and temporary gauging stations at the start and end of each section, and recorded water levels at two-hour intervals to assess lag times and transmission losses. Anderson and Morison (1989) also measured lag times and some transmission losses for a natural flood and two controlled releases in the Wimmera River and MacKenzie River.

Transmission losses and lag times vary with flow size and with season. More monitoring is therefore required to assess losses associated with large flow releases in the Glenelg River and with a range of different flow releases in the Wimmera system. Hydrological measurements throughout individual reaches may be used to identify points with high transmission losses. Decisions can then be made to either reduce these losses, increase releases to achieve environmental flow targets or use alternative environmental flow release points. This assessment will be particularly important in the Wimmera system where environmental flows can be controlled through a combination of different release points.

Existing VWQMN gauging stations may be used to assess discharge rates, transmission losses and lag times in some reaches, but temporary gauging stations may also be required to measure flow at various locations within each reach. For example, more gauging stations may be needed in the Glenelg River between Rocklands Reservoir and the Chetwynd River where hydrological changes are likely to be pronounced, than in reaches further downstream. Finer scale measurements at specified cross sections may also be needed to assess changes to the flow regime in tributaries such as the MacKenzie River and Burnt Creek that have flow targets in the order of 1-2 ML/day. Flow measurements at temporary gauging stations and cross sections may be labour intensive, but they only need to be done once for each flow.

In summary, we recommend that field sites used in the Stressed Rivers and Bulk Entitlement studies be used to assess whether hydraulic targets for environmental flow releases are being met. Less detailed visual inspections should also be conducted to determine whether particular flow components are delivered throughout each reach. Data from VWQMN gauging stations should be used to assess discharge before, during and after environmental flow releases and additional temporary gauging stations should be established in certain reaches to assess transmission losses and lag times. These assessments will need to be done under different flow conditions to assess the delivery of specific flow components, but they only need to be done once for each flow component, unless flow allocations vary substantially across years.

7.5.4 Biology

Macroinvertebrates

Macroinvertebrates are a major component of most river health monitoring done in Australia and in Victoria. There is considerable evidence that macroinvertebrate assemblages can be useful indicators of high nutrient input e.g. SIGNAL scores, (Chessman, 2003); EPT scores, (Wallace, *et al.*, 1996). Reference condition monitoring, such as AusRivAS, uses the difference between the families observed at a site and the predicted families based on reference sites with less human interference. This approach is part of both National River Health monitoring and the Victorian Index of Stream Condition.

In contrast, we have little information on how invertebrates might respond to changing flow regimes and this is an active area of research in Australia and overseas. As a consequence, it is difficult to predict how sensitive AusRivAS scores or the invertebrate component of the Victorian Index of Stream Condition (ISC) will be to the implementation of environmental flow regimes. Environmental flows are likely to improve the quality, quantity and diversity of macroinvertebrate habitats. Improved water quality is likely to lead to an increase in the relative abundance of sensitive taxa in pools, while the inundation of snags, macrophytes and runs will increase the diversity of potential habitats and may therefore increase overall macroinvertebrate diversity within these streams. Coarse measures such as AusRivAS models and SIGNAL scores may detect large changes to the type of families present at particular sites, but more sensitive techniques that compare the relative abundance of common taxa identified to the lowest taxonomic level are more likely to illustrate responses to environmental flows.

Nonetheless, there are two reasons why macroinvertebrates might be part of a monitoring program to detect responses to environmental flows in the Wimmera and Glenelg Rivers. First, improvements in river health in response to altered flows will be an important measure of success of environmental flows for management agencies and the community. River health monitoring is now standard practice in Victoria and such monitoring routinely includes macroinvertebrates, so incorporating it in this monitoring program may be cost-effective. Second, some of the best existing baseline data we have for these two rivers are for macroinvertebrates, through the Victorian EPA and the work done by the research group at Deakin University at Warrnambool.

The difficulty with macroinvertebrates in rivers and streams is their well-documented variability at a range of spatial and temporal scales, especially small spatial scales (Brooks, *et al.*, 2002; Downes, *et al.*, 1993). The implication is that trends through time, or differences between sites or reaches, may be obscured by an inadequate sampling regime failing to incorporate this small-scale variability. Unfortunately, a detailed monitoring design for macroinvertebrates is difficult without quantifying this variability. The only dataset that would be adequate for detailed analysis of Macroinvertebrate variability in the Wimmera and Glenelg Rivers is that collected by Peter Lind from Deakin University at Warrnambool (working with Assoc Prof Brad Mitchell and Dr Belinda Robson). While these data were not available for this report, as Peter is writing his PhD thesis, we strongly recommend that once the thesis is finalised, these data and Peter's results be examined and further analysed to assess variability in macroinverebrate assemblages at different spatial and temporal scales. Until this is done, there is little justification for expanding beyond the current level of macroinvertebrate monitoring.

Therefore, we recommend continuing the Victorian River Health monitoring through the ISC, and also the Victorian EPA program that has been monitoring macroinvertebrates at specific sites in the Wimmera River for a number of years. Routine ISC monitoring is supposed to occur in Autumn and Spring every five to seven years, however only a subset of ISC sites are monitored on each sampling occasion and half of the previously monitored sites will not be sampled again. If the CMAs wish to use macroinvertebrates for assessing changes in the short-term (next 3 to 5 years), then monitoring at the key sites described in Table 7-2 in spring and autumn every two or three years, using Standard EPA Rapid Bioassessment methods (Tiller, Metzeling, 1998), is recommended. However, we emphasise that we cannot be confident that such monitoring will detect responses to environmental flows in these rivers until variability in macroinvertebrate populations and assemblages at different spatial and temporal scales has been analysed. Again, the data of Metzeling *et al*. from the Victorian EPA and the data from Lind *et al*. at Warrnambool will be the most appropriate for these analyses and may also identify key taxa that respond to flow changes. The monitoring must ensure that habitat type is not a confounding factor, so habitats that are common across most sites need to be sampled, e.g. littoral (edge) zones.

A major constraint on the interpretation of macroinvertebrate data is that the past five years have been very dry in both catchments and the macroinvertebrate assemblages in the Wimmera in particular are in very poor condition (L. Metzeling, pers comm.). While this means that environmental flows are likely to elicit a response in macroinvertebrates, even just because of an increase in wetted habitat, it will be very difficult to distinguish responses to environmental flows from recovery from drought even if environmental flows were not released. The only partial solution to this problem is to monitor for a long time period so that trends over periods without drought can be assessed.

Fish

Species composition and relative abundance of native and exotic fish species are key variables. Maintaining and enhancing native fish populations are primary objectives of the environmental flows in both rivers and there is some evidence linking fish life-histories with flow. Distributions of some fish species are also linked closely to hydraulic habitat, e.g. river blackfish (Koehn, 1986). However, most importantly, native fish are highly regarded by most stakeholders as indicators of a "healthy" river and as valuable assets that must be protected. It would be difficult to defend a monitoring program to stakeholders that didn't include native fish.

Ideally, fish surveys would be conducted at all key sites in each reach and at additional sites in reaches that will be used for specific contrasts. However, there are 32 key sites and the inclusion of additional sites would lead to a large and expensive sampling program. If only a subset of sites in each reach can be sampled, we recommend choosing sites that have existing fish data – these are identified in Table 7.1. The exception might be that it is also worth sampling sites within reaches that currently have very little (or even no water) under current regulated flows, and hence no previous fish data, but will receive water under environmental flows. Demonstrating that such sites (and reaches) can recover native fish populations would be an important demonstration of benefits of environmental flows. Such sites might include those directly downstream of Huddleston Weir and in Burnt Creek and the MacKenzie River downstream of the Toolondo Channel. As with the other components of this monitoring program, having good long-term data through time at specific sites is a higher priority than sampling many sites less frequently and contrasting reaches.

We recommend a combination of methods at a site. Backpack electrofishing, fyke nets, bait traps and possibly seine nets should be used, with sampling done in late spring or early summer each year when there is moderate water in the streams and warm temperatures ensure that fish are relatively active. Backpack electrofishing is not effective in highly saline water (>1500 μS) and therefore it may only be possible to use fyke nets, bait traps and seine nets at some sites. It is important that staff experienced in fish sampling are used, as decisions about location of nets etc. often need to be made at short notice in the field. Population structure and size class distributions are straightforward to determine once fish have been captured. Samples are processed in the field, with all fish caught being identified, counted and their lengths measured. Native fish should be returned to the water but exotic species should be humanely destroyed. Relevant variables will be species richness, fish assemblage composition (based on presence-absence), relative abundances of different species and population size-structures.

The cost of sampling would be two people per site per day. Only one site could be completed in a day, as fyke nets and bait traps need to be deployed over a 12 hour period, again suggesting that only a subset of sites in a reach could feasibly be included as part of monitoring fish populations.

Second tier variables would include larval stages of fish as a measure of reproductive success. However, although some studies have demonstrated links to flow regimes (e.g. Campaspe Flow Manipulation Experiment), larval sampling is expensive and needs to be done frequently to ensure that peak larval abundance is recorded for the main species. We recommend this component only be done if it is part of a research project with a partner institution, e.g. through a University project.

River Health

The Index of Stream Condition (ISC) uses various measures of hydrology, physical form, streamside zone, water quality and aquatic life to assess the reach scale health of Victorian rivers and streams. It was used to determine the benchmark condition of Victoria's rivers and streams in 1999 and is supposed to be repeated every five years. The 1999 assessment included 20 reaches in the Glenelg and Wannon Rivers and 17 reaches in the Wimmera and MacKenzie Rivers and Mt William Creek. Data from VWQMN and EPA monitoring sites were used to score water quality, and aquatic life indices and index scores were estimated at some reaches that did not have routine monitoring.

Environmental flows are likely to affect some of the indicators used in the ISC assessment, but will not influence floodplain parameters and broad catchment indices. The overall ISC assessment may therefore not provide a very sensitive test of river health changes due to environmental flow releases. A better approach may be to correlate changes to in-channel ISC indicators (which are likely to be dependent on flow) with environmental flow releases. These indicators may include AusRivAS and SIGNAL scores for macroinvertebrate communities, water quality, regeneration of indigenous woody vegetation, instream physical habitat and annual flow deviation. Many of these indices will be measured for other parts of the monitoring program and therefore this assessment will primarily involve the re-analysis of that data in-between scheduled ISC sampling years. The ongoing ISC program can be used to assess overall changes in river health every five years.

It should be noted that aquatic life scores were reasonably high in the 1999 ISC assessment of the Wimmera and Glenelg Rivers, and therefore changes due to environmental flow releases may be difficult to detect. Macroinvertebrate communities were not routinely sampled in Victoria before the 1970s and therefore we have no indication of what communities existed in the Wimmera and Glenelg Rivers prior to regulation. Current macroinvertebrate communities in the Wimmera and Glenelg systems are typical of lowland streams (Doeg, 2000) and are dominated by taxa that can tolerate high salinity, low dissolved oxygen and high turbidity. Schreiber (Schreiber, *et al.*, 1998) suggested that the high AusRivAS scores reported for these rivers could be due to the degraded condition of communities at reference sites. The EPA reference sites for the Wimmera and Glenelg rivers are in regulated reaches and therefore suffer many of the impacts that environmental flow allocations aim to address. For this reason, we may expect little or no improvement in AusRivAS scores as a result of environmental flows. However, environmental flows should increase the quality and quantity of macroinvertebrate habitats by inundating vegetation and other habitat elements and by improving water quality. As a result of these habitat changes we would expect to see an increase in the relative abundance of sensitive taxa and an associated shift in macroinvertebrate community composition.

Most of the relevant components of the ISC are part of the monitoring program we have described, including water quality, hydrology, physical habitat and macroinvertebrates. Therefore, this monitoring program will be able to calculate measures of river health at the selected sites and detect changes in health through time.

7.5.5 Short- versus long-term monitoring

One of the major constraints on the design of monitoring programs to detect responses to environmental flows is that we don’t know the likely response times for many of the variables. We do know that some components of the biota, and some geomorphological aspects, may take a long time (years or tens of years) to respond. For example, some riparian species are long-lived (River Redgums) and we wouldn’t expect rapid changes in abundance or population structure. Nonetheless, it is important for management agencies to be able to demonstrate shorter-term (less than 5 years) responses to water allocations and even responses to individual components of an environmental flow regime, e.g. a summer fresh.

Of the variables we have recommended, there are three that would potentially respond to environmental flows in the shorter term. The most obvious is flow itself – it is important that the environmental flow regime results in water reaching sites and having the desired effects (as specified in the environmental flow objectives for each reach and site) in terms of creating wetted habitat. Observations at SKM cross-section sites during environmental flows should test whether the flows are producing the desired hydrological (and at a coarse scale, hydraulic) responses.

The second variable is water quality, in particular salinity (measured by conductivity) and dissolved oxygen in pools. Improving water quality in pools over summer, and reducing overall salinity levels especially in the Wimmera River, are major objectives of the environmental flow regime and short-term responses would be expected. Monthly measurements should show any trends in water quality in pools, especially if compared with previous data, and measurements before and after summer freshes would test whether such events improve water quality in pools.

Finally, spring freshes to enhance native fish recruitment are part of the environmental flow objectives. While fish recruitment is likely to be patchy, both spatially and temporally, it is also likely to change in the short-term in response to modified flow conditions. So measuring abundance/diversity of fish larvae at sites that receive spring freshes compared with sites that don’t may be informative. The difficulty is the cost (in time and equipment) of sampling fish larvae and the expertise required for identification (although the CRCFE is producing a key). A more practical option may be to use standard fish sampling techniques described in section 7.5.4 and use the relative abundance of juveniles caught in early summer as an indication of successful recruitment.

- **Table 7-3 Summary of recommended response variables to be recorded at each site in the Wimmera and Glenelg Rivers, with specific methods and spatial and temporal frequency of sampling.**

Variable	Methods	Spatial design	Temporal design
Water quality Key: pH, DO, EC, Temp, Turbidity Second tier: Total N and total P, the latter also required for ISC	Appropriate portable meter, collect water samples for laboratory analysis for any nutrient analyses. Nutrients probably not required in pools and VWQMN data will probably suffice for this.	Water quality will need to be recorded in pools at each site. All Wimmera reaches except Burnt Creek and all Glenelg Reaches except Chetwynd-Wannon have active VWQMN stations. These stations should be used and additional in-situ measures should be taken at other sites.	Water is sampled monthly at VWQMN sites. These data should be used. Key parameters should also be measured monthly at additional sites during summer (November to April) when water quality is likely to be a problem.
Channel morphology and vegetation Key: Measures the extent and composition of terrestrial vegetation in the channel. Measure short term changes to size and distribution of in channel habitats associated with specific flow components.	Measure the extent of terrestrial vegetation within the channel from fixed points (photo points may be useful) and use quadrats to assess in channel vegetation composition at each site. Survey fixed cross section and longitudinal sections at each channel using a total station to assess changes to in channel features. Photo points	Vegetation needs to be monitored at multiple cross sections and a longitudinal section at each site. Exactly the same sections need to be surveyed on each occasion to accurately assess temporal changes	Vegetation surveys should probably be done every 2-3 years but should be done in the same season each time (probably summer). Small responses to specific flow releases will be very rapid, therefore need to monitor before and immediately after particular flows.

Variable	**Methods**	**Spatial design**	**Temporal design**
Second tier: Measure the size, extent and distribution of in channel features such as bars, benches and pool depth etc. It may not be possible to attribute long term changes to environmental flows.	and direct measurements of habitat (e.g. pool dimensions) more useful for short term changes		Geomorphological responses to overall flow regime likely to take longer, therefore only need to monitor longitudinal channel features every five years or so (this could possibly coincide with ISC monitoring).
Hydrology Measure discharge, water levels and wetted perimeter during specific flow events to test flow predictions. Measure transmission losses and lag times for different flow releases.	Measure discharge, water levels and wetted perimeter during specific flow releases. Use previous SKM cross section sites and VWQMN gauging stations where they exist. Visual assessments of water levels at other sites in each reach. Measure water height and discharge at set time intervals at established and temporary gauging stations during flow events to determine transmission losses and lag times.	Measure at sites used for Stressed Rivers and Bulk Entitlement studies, also use existing gauging stations. Visual assessments at other sites in each reach. Temporary gauging stations may need to be established at the top and bottom of identified sections (natural stream reaches) within each reach to determine transmission losses and lag times within each reach.	Probably only needs to be done once for each flow component in each reach. NB. If flows are introduced gradually over several years then may need to be done several times.

Variable	**Methods**	**Spatial design**	**Temporal design**
Macroinvertebrates Macroinvertebrate community data	Using EPA protocols for rapid bioassessment. Composite sweep sample at each site, live picking and identification to family-level.	One composite sweep (and kick if riffles are present) sample at each key site. Composite samples should proportionally sample macrophyte, snag and substrate sub-habitats in each pool or riffle. Data from future EPA and ISC monitoring at additional sites can be used to supplement data from key sites.	Sample Autumn and Spring every second or third year. Annual sampling probably too expensive for no obvious benefit.
Fish	Backpack electrofishing by qualified person. Fyke nets set out overnight, ensuring end out of water so don’t drown mammals or diving birds. Bait traps set overnight near snags or emergent vegetation.	Three replicate pools at each site	Sampling in summer only, focusing on pools at each site.

7.6 Analysis

It is difficult to be prescriptive about statistical analyses and interpretations of the data from this monitoring program because specific details about how and when environmental flows will be released have not been decided, except in the very short-term. We can identify four broad analytical strategies that are likely to be used. Note that in most cases, the response variables we have recommended are quantitative variables (e.g. EC, DO, species richness, ISC score etc.) so parametric analyses that assume a particular distribution of the response variable are appropriate. For some qualitative variables (e.g. habitat), the results may simply be descriptive and interpretations more cautious.

1. The emphasis in this monitoring design is the measurement of temporal trends in key response variables at selected sites. The general analyses will be appropriate time-series and/or linear model methods, where the value of the response variable is modelled against time as the predictor variable. Various types of linear and non-linear trends can be assessed with these methods. Note that the power of these analyses is determined by the number of sampling times, so they are most appropriate for detecting longer-term trends. If there are enforced changes in the environmental flow regime, e.g. years when more or less water is allocated than expected, we would expect deviations in the longer-term trends that can be tested with methods such as intervention analysis.

2. Specific temporal contrasts, between sets of years or before and after a particular flow event, will be appropriate in some situations. For example, comparing data from 1996-1998 (Mitchell et al., Deakin University) to a comparably wet period in the future might minimise the confounding effects of the past five years of drought. Also, if the environmental flows focus on improving water quality and fish habitat in pools over summer, then comparing DO and EC in pools before and after a flow event would be relevant. Such temporal contrasts can be analysed using standard linear models (e.g. ANOVA designs).

3. Comparison of reaches may be relevant if some reaches clearly receive more water under the environmental flow regime than others. For example, comparison of the responses of the reach upstream of Glenorchy (little environmental allocation) to the reach between Glenorchy and Huddleston (some environmental allocation) will provide some evidence of whether changes in the latter reach are greater than what would occur naturally. For specific flow events, this spatial contrast could also incprorate before and after sampling. Analysis again would be using linear ANOVA models with sites within each reach as replicate units.

4. Finally, multivariate comparisons of assemblages of macroinvertebrates or fish through time and between reaches will be appropriate. Ordination methods (e.g. multidimensional

scaling based on suitable dissimilarity indices such as Bray-Curtis) should be used with specific spatial (between reach) or temporal (between years or before and after events) contrasts using ANOSIM (analysis of similarities) or NPMANOVA (non-parametric multivariate analysis of variance).

Data from initial monitoring of water quality during the first year should be analysed as soon as possible to assess spatial variability (between replicates and between sites). Such analyses can then be used to assess the adequacy of replication at these two scales (sites and replicates within sites) using power analysis and cost-benefit analysis (see (Downes, *et al.*, 2002; Quinn, Keough, 2002). The monitoring design can then be adjusted to increase or decrease the replication at either scale. Existing data may also be suitable for such analyses. For example, the VWQMN data should be adequate for measuring temporal variability for specific sites, as well as site to site variability within a reach. Also, as mentioned above, the extensive macroinvertebrate sampling by Lind et al. from Deakin University should be analysed to assess both spatial and temporal variability before any new macroinvertebrate monitoring, beyond the routine ISC sampling, is initiated.

We also emphasise the importance of consistency and reliability in data collection and storage. There are many examples of monitoring programs than have been ineffective because the data were not collected in a consistent manner (due to different staff doing the fieldwork or data entry) or the data storage was not reliable. A short field methods manual should be produced to ensure that consistent methods are used throughout the monitoring program. It is also essential that a data management plan be established at the start of the monitoring program, including standardised field data sheets, instructions for electronic data entry and a central database for data storage and manipulation. This last point is particularly important if different groups (CMAs, consulting organisations, research providers) are doing different components of the monitoring.

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Appendix A Site by site monitoring schedule

Table A-8-1 identifies two key sites within each study reach that will form the basis of the environmental flows monitoring program. These sites have either been used in previous studies to determine environmental flow recommendations or are current VWQMN sites. Water quality, hydrological, geomorphological, fish and macroinvertebrate data collected from these sites will be used to assess temporal changes associated with environmental flow releases. Additional sites with existing data have been identified in each reach. It will probably not be feasible to monitor temporal trends at all of these additional sites, but specific parameters should be monitored at some of these sites to increase the statistical power of spatial contrasts between reaches that do and do not receive environmental flows. We recommend that water quality assessments and fish surveys be conducted at these additional sites, as these will test the main objectives of the environmental flow releases. Visual hydrological assessments should also be done at these sites to assess how flow releases affect water levels throughout each reach. The EPA periodically monitors macroinvertebrate communities at a number of these additional sites, and these data should be used to supplement data from key sites. The final choice of additional monitoring sites will need to be made by the Wimmera and Glenelg-Hopkins CMAs once flow allocations for each reach are known, as this will determine the relevant spatial contrasts.

Data collected from the key sites recommended in this study are intended to provide an overall assessment of conditions in each particular reach. The Wimmera and Glenelg-Hopkins CMAs may also choose to monitor changes at specific sites with known ecological or geomorphological threats. For example, additional geomorphology monitoring may be desirable at sites with known erosion problems or where sand infilling is severe. These sites should be selected by CMA staff or other people with a detailed knowledge of the Wimmera and Glenelg systems, but should be considered additional to the key sites prescribed in this report. Monitoring at these sites should test specific hypotheses described for each reach in Section 7.3 of this report.

Extra hydrology monitoring may also be required at a number of sites in order to assess transmission losses and lag times associated with environmental flow releases. Transmission losses need to be measured in order to calculate or adjust discharge rates to provide the recommended environmental flows. However, this task is separate to monitoring the effect of environmental flow releases and is not included in the recommended monitoring schedule outlined below.

- **Table A-8-1 Recommended monitoring sites for the reaches in the Wimmera and Glenelg catchments. The table includes a description of previous studies that have used each site and gives a grid reference location.**

Recommended monitoring sites	Variable	Monitoring frequency
Upper Wimmera		
KEY SITE: Glynwylln VWQMN site 415206 Will need to establish cross sections at this site	Water Quality: Measure DO, EC, pH, temp at surface and depth in pools	Monthly Additional event monitoring to assess changes after freshes
	Hydrology: Measure discharge and water levels Visually assess flow and habitat inundation	During flow events Only needs to be done once for each flow type not repeated each year.
	Geomorphology: Measure pool dimensions, sediment deposition, distribution of debris (photo points and/or direct measurement may be used)	Short term responses measure before and after specific flow events. Only needs to be done once for each flow type
	Geomorphology: Measure channel cross sections and longitudinal sections, vegetation extent and vegetation composition.	Every 3-5 years but should always be done in summer to accurately measure vegetation.
	Macroinvertebrates: Standard EPA Rapid Bioassessment techniques	Autumn & Spring every 3-5 years
	Fish: Various sampling techniques	Early summer every 3-5 years but will need to be done more frequently if trying to detect responses to specific flow releases such as spring freshes.
KEY SITE: Cambells Bridge **(Stawell Donald Rd)** EPA site IIM	Water Quality: Measure DO, EC, pH, temp at surface and depth in pools	Monthly Additional event monitoring to assess changes after freshes

Recommended monitoring sites	Variable	Monitoring frequency
	Hydrology: Measure discharge and water levels Visually assess flow and habitat inundation	During flow events Only needs to be done once for each flow type not repeated each year.
	Geomorphology: Measure pool dimensions, sediment deposition, distribution of debris (photo points and/or direct measurement may be used)	Short term responses measure before and after specific flow events. Only needs to be done once for each flow type
	Geomorphology: Measure channel cross sections and longitudinal sections, vegetation extent and vegetation composition.	Every 3-5 years but should always be done in summer to accurately measure vegetation.
	Macroinvertebrates: Standard EPA Rapid Bioassessment techniques	Autumn & Spring every 3-5 years
	Fish: Various sampling techniques	Early summer every 3-5 years but will need to be done more frequently if trying to detect responses to specific flow releases such as spring freshes.
Joel Joel Bridge EPA site IIL	Water Quality: Measure DO, EC, pH, temp at surface and depth in pools	Monthly Additional event monitoring to assess changes after freshes
	Hydrology: Visually assess flow and habitat inundation	During flow events Only needs to be done once for each flow type not repeated each year.
	Macroinvertebrates: Standard EPA Rapid Bioassessment techniques	Sample as part of ongoing EPA monitoring programs.
	Fish: Various sampling techniques	Early summer every 3-5 years but will need to be done more frequently if trying to detect responses to specific flow releases such as spring freshes.

Recommended monitoring sites	**Variable**	**Monitoring frequency**
Glenorchy (Stawell – Warracknabeal Rd) Mitchell & Lind study site	Water Quality: Measure DO, EC, pH, temp at surface and depth in pools	Monthly Additional event monitoring to assess changes after freshes
	Hydrology: Visually assess flow and habitat inundation	During flow events Only needs to be done once for each flow type not repeated each year.
	Fish: Various sampling techniques	Early summer every 3-5 years but will need to be done more frequently if trying to detect responses to specific flow releases such as spring freshes.
Hunts Rd (off Glenorchy – Campbells Bridge Rd) No Data	Water Quality: Measure DO, EC, pH, temp at surface and depth in pools	Monthly Additional event monitoring to assess changes after freshes
	Hydrology: Visually assess flow and habitat inundation	During flow events Only needs to be done once for each flow type not repeated each year.
	Fish: Various sampling techniques	Early summer every 3-5 years but will need to be done more frequently if trying to detect responses to specific flow releases such as spring freshes.
Glenorchy Weir to Huddleston Weir		
KEY SITE: Daves Lane SKM cross section	Water Quality: Measure DO, EC, pH, temp at surface and depth in pools	Monthly Additional event monitoring to assess changes after freshes
	Hydrology: Measure discharge and water levels Visually assess flow and habitat inundation	During flow events Only needs to be done once for each flow type not repeated each year.

Recommended monitoring sites	Variable	Monitoring frequency
	Geomorphology: Measure pool dimensions, sediment deposition, distribution of debris (photo points and/or direct measurement may be used)	Short term responses measure before and after specific flow events. Only needs to be done once for each flow type
	Geomorphology: Measure channel cross sections and longitudinal sections, vegetation extent and vegetation composition.	Every 3-5 years but should always be done in summer to accurately measure vegetation.
	Macroinvertebrates: Standard EPA Rapid Bioassessment techniques	Autumn & Spring every 3-5 years
	Fish: Various sampling techniques	Early summer every 3-5 years but will need to be done more frequently if trying to detect responses to specific flow releases such as spring freshes.
KEY SITE: Glenorchy Weir tail gauge VWQMN site 415201 & EPA site IHJ	Water Quality: Measure DO, EC, pH, temp at surface and depth in pools	Monthly Additional event monitoring to assess changes after freshes
	Hydrology: Measure discharge and water levels Visually assess flow and habitat inundation	During flow events Only needs to be done once for each flow type not repeated each year.
	Geomorphology: Measure pool dimensions, sediment deposition, distribution of debris (photo points and/or direct measurement may be used)	Short term responses measure before and after specific flow events. Only needs to be done once for each flow type
	Geomorphology: Measure channel cross sections and longitudinal sections, vegetation extent and vegetation composition.	Every 3-5 years but should always be done in summer to accurately measure vegetation.
	Macroinvertebrates: Standard EPA Rapid Bioassessment techniques	Autumn & Spring every 3-5 years

Recommended monitoring sites	Variable	Monitoring frequency
	Fish: Various sampling techniques	Early summer every 3-5 years but will need to be done more frequently if trying to detect responses to specific flow releases such as spring freshes.
Ledcourt Rd No Data	Water Quality: Measure DO, EC, pH, temp at surface and depth in pools	Monthly Additional event monitoring to assess changes after freshes
	Hydrology: Measure discharge and water levels Visually assess flow and habitat inundation	During flow events Only needs to be done once for each flow type not repeated each year.
	Fish: Various sampling techniques	Early summer every 3-5 years but will need to be done more frequently if trying to detect responses to specific flow releases such as spring freshes.
Companys Bridge No Data	Water Quality: Measure DO, EC, pH, temp at surface and depth in pools	Monthly Additional event monitoring to assess changes after freshes
	Hydrology: Measure discharge and water levels Visually assess flow and habitat inundation	During flow events Only needs to be done once for each flow type not repeated each year.
	Fish: Various sampling techniques	Early summer every 3-5 years but will need to be done more frequently if trying to detect responses to specific flow releases such as spring freshes.
U/S Huddleston Weir No Data	Water Quality: Measure DO, EC, pH, temp at surface and depth in pools	Monthly Additional event monitoring to assess changes after freshes

Recommended monitoring sites	Variable	Monitoring frequency
	Hydrology: Measure discharge and water levels Visually assess flow and habitat inundation	During flow events Only needs to be done once for each flow type not repeated each year.
	Fish: Various sampling techniques	Early summer every 3-5 years but will need to be done more frequently if trying to detect responses to specific flow releases such as spring freshes.
Huddleston Weir to Lake Taylor Outlet Note if water released from Huddleston Weir then this reach and the next should be combined and only two key sites will be needed in total.		
KEY SITE: D/S Huddleston Weir SKM cross section	Water Quality: Measure DO, EC, pH, temp at surface and depth in pools	Monthly Additional event monitoring to assess changes after freshes
	Hydrology: Measure discharge and water levels Visually assess flow and habitat inundation	During flow events Only needs to be done once for each flow type not repeated each year.
	Geomorphology: Measure pool dimensions, sediment deposition, distribution of debris (photo points and/or direct measurement may be used)	Short term responses measure before and after specific flow events. Only needs to be done once for each flow type
	Geomorphology: Measure channel cross sections and longitudinal sections, vegetation extent and vegetation composition.	Every 3-5 years but should always be done in summer to accurately measure vegetation.
	Macroinvertebrates: Standard EPA Rapid Bioassessment techniques	Autumn & Spring every 3-5 years
	Fish: Various sampling techniques	Early summer every 3-5 years but will need to be done more frequently if trying to detect responses to specific flow releases such as spring freshes.

Recommended monitoring sites	Variable	Monitoring frequency
KEY SITE: Halls Island SKM cross section	Water Quality: Measure DO, EC, pH, temp at surface and depth in pools	Monthly Additional event monitoring to assess changes after freshes
	Hydrology: Measure discharge and water levels Visually assess flow and habitat inundation	During flow events Only needs to be done once for each flow type not repeated each year.
	Geomorphology: Measure pool dimensions, sediment deposition, distribution of debris (photo points and/or direct measurement may be used)	Short term responses measure before and after specific flow events. Only needs to be done once for each flow type
	Geomorphology: Measure channel cross sections and longitudinal sections, vegetation extent and vegetation composition.	Every 3-5 years but should always be done in summer to accurately measure vegetation.
	Macroinvertebrates: Standard EPA Rapid Bioassessment techniques	Autumn & Spring every 3-5 years
	Fish: Various sampling techniques	Early summer every 3-5 years but will need to be done more frequently if trying to detect responses to specific flow releases such as spring freshes.
Faux's Bridge EPA site IHB	Water Quality: Measure DO, EC, pH, temp at surface and depth in pools	Monthly Additional event monitoring to assess changes after freshes
	Hydrology: Visually assess flow and habitat inundation	During flow events Only needs to be done once for each flow type not repeated each year.
	Macroinvertebrates: Standard EPA Rapid Bioassessment techniques	Sample as part of ongoing EPA monitoring programs.

Recommended monitoring sites	Variable	Monitoring frequency
	Fish: Various sampling techniques	Early summer every 3-5 years but will need to be done more frequently if trying to detect responses to specific flow releases such as spring freshes.
No other accessible sites in this reach		
Lake Taylor Outlet to MacKenzie River		
KEY SITE: Gross' Bridge SKM cross section	Water Quality: Measure DO, EC, pH, temp at surface and depth in pools	Monthly Additional event monitoring to assess changes after freshes
	Hydrology: Measure discharge and water levels Visually assess flow and habitat inundation	During flow events Only needs to be done once for each flow type not repeated each year.
	Geomorphology: Measure pool dimensions, sediment deposition, distribution of debris (photo points and/or direct measurement may be used)	Short term responses measure before and after specific flow events. Only needs to be done once for each flow type
	Geomorphology: Measure channel cross sections and longitudinal sections, vegetation extent and vegetation composition.	Every 3-5 years but should always be done in summer to accurately measure vegetation.
	Macroinvertebrates: Standard EPA Rapid Bioassessment techniques	Autumn & Spring every 3-5 years
	Fish: Various sampling techniques	Early summer every 3-5 years but will need to be done more frequently if trying to detect responses to specific flow releases such as spring freshes.
KEY SITE: Horsham Rifle Range SKM cross section	Water Quality: Measure DO, EC, pH, temp at surface and depth in pools	Monthly Additional event monitoring to assess changes after freshes

Recommended monitoring sites	Variable	Monitoring frequency
	Hydrology: Measure discharge and water levels Visually assess flow and habitat inundation	During flow events Only needs to be done once for each flow type not repeated each year.
	Geomorphology: Measure pool dimensions, sediment deposition, distribution of debris (photo points and/or direct measurement may be used)	Short term responses measure before and after specific flow events. Only needs to be done once for each flow type
	Geomorphology: Measure channel cross sections and longitudinal sections, vegetation extent and vegetation composition.	Every 3-5 years but should always be done in summer to accurately measure vegetation.
	Macroinvertebrates: Standard EPA Rapid Bioassessment techniques	Autumn & Spring every 3-5 years
	Fish: Various sampling techniques	Early summer every 3-5 years but will need to be done more frequently if trying to detect responses to specific flow releases such as spring freshes.
Wimmera River at Horsham VWQMN site 415200	Water Quality: Measure DO, EC, pH, temp at surface and depth in pools	Monthly Additional event monitoring to assess changes after freshes
	Hydrology: Measure discharge and water levels Visually assess flow and habitat inundation	During flow events Only needs to be done once for each flow type not repeated each year.
	Fish: Various sampling techniques	Early summer every 3-5 years but will need to be done more frequently if trying to detect responses to specific flow releases such as spring freshes.

Recommended monitoring sites	Variable	Monitoring frequency
1.5 km South of Monument upstream of Horsham EPA site IHC (reference site including airlift)	Water Quality: Measure DO, EC, pH, temp at surface and depth in pools	Monthly Additional event monitoring to assess changes after freshes
	Hydrology: Visually assess flow and habitat inundation	During flow events Only needs to be done once for each flow type not repeated each year.
	Macroinvertebrates: Standard EPA Rapid Bioassessment techniques	Sample as part of ongoing EPA monitoring programs.
	Fish: Various sampling techniques	Early summer every 3-5 years but will need to be done more frequently if trying to detect responses to specific flow releases such as spring freshes.
Dooens Swamp Water EcoScience invertebrate and fish data.	Water Quality: Measure DO, EC, pH, temp at surface and depth in pools	Monthly Additional event monitoring to assess changes after freshes

Recommended monitoring sites	Variable	Monitoring frequency
	Hydrology: Visually assess flow and habitat inundation	During flow events Only needs to be done once for each flow type not repeated each year.
	Fish: Various sampling techniques	Early summer every 3-5 years but will need to be done more frequently if trying to detect responses to specific flow releases such as spring freshes.
Wimmera River: MacKenzie River to Lake Hindmarsh		
KEY SITE: O'Brees Crossing SKM cross section	Water Quality: Measure DO, EC, pH, temp at surface and depth in pools	Monthly Additional event monitoring to assess changes after freshes Consider installing continuous EC and DO monitors at Polkemmet downstream of this site
	Hydrology: Measure discharge and water levels Visually assess flow and habitat inundation	During flow events Only needs to be done once for each flow type not repeated each year.
	Geomorphology: Measure pool dimensions, sediment deposition, distribution of debris (photo points and/or direct measurement may be used)	Short term responses measure before and after specific flow events. Only needs to be done once for each flow type
	Geomorphology: Measure channel cross sections and longitudinal sections, vegetation extent and vegetation composition.	Every 3-5 years but should always be done in summer to accurately measure vegetation.
	Macroinvertebrates: Standard EPA Rapid Bioassessment techniques	Autumn & Spring every 3-5 years

Recommended monitoring sites	Variable	Monitoring frequency
	Fish: Various sampling techniques	Early summer every 3-5 years but will need to be done more frequently if trying to detect responses to specific flow releases such as spring freshes.
KEY SITE: Horseshoe Bend SKM cross section & EPA site IJF reference site	Water Quality: Measure DO, EC, pH, temp at surface and depth in pools	Monthly Additional event monitoring to assess changes after freshes Consider installing continuous EC and DO monitors at this site
	Hydrology: Measure discharge and water levels Visually assess flow and habitat inundation	During flow events Only needs to be done once for each flow type not repeated each year.
	Geomorphology: Measure pool dimensions, sediment deposition, distribution of debris (photo points and/or direct measurement may be used)	Short term responses measure before and after specific flow events. Only needs to be done once for each flow type
	Geomorphology: Measure channel cross sections and longitudinal sections, vegetation extent and vegetation composition.	Every 3-5 years but should always be done in summer to accurately measure vegetation.
	Macroinvertebrates: Standard EPA Rapid Bioassessment techniques	Autumn & Spring every 3-5 years
	Fish: Various sampling techniques	Early summer every 3-5 years but will need to be done more frequently if trying to detect responses to specific flow releases such as spring freshes.

Recommended monitoring sites	Variable	Monitoring frequency
Lochiel Railway Bridge VWQMN site 415246	Water Quality: Measure DO, EC, pH, temp at surface and depth in pools	Monthly Additional event monitoring to assess changes after freshes
	Hydrology: Measure discharge and water levels Visually assess flow and habitat inundation	During flow events Only needs to be done once for each flow type not repeated each year.
	Fish: Various sampling techniques	Early summer every 3-5 years but will need to be done more frequently if trying to detect responses to specific flow releases such as spring freshes.
Kenny's Ford EPA site IHI airlift & Mitchell and Lind site	Water Quality: Measure DO, EC, pH, temp at surface and depth in pools	Monthly Additional event monitoring to assess changes after freshes
	Hydrology: Visually assess flow and habitat inundation	During flow events Only needs to be done once for each flow type not repeated each year.
	Macroinvertebrates: Standard EPA Rapid Bioassessment techniques	Sample as part of ongoing EPA monitoring programs.
	Fish: Various sampling techniques	Early summer every 3-5 years but will need to be done more frequently if trying to detect responses to specific flow releases such as spring freshes.
D/S Dimboola Weir EPA site IHK airlift and reference site	Water Quality: Measure DO, EC, pH, temp at surface and depth in pools	Monthly Additional event monitoring to assess changes after freshes
	Hydrology: Visually assess flow and habitat inundation	During flow events Only needs to be done once for each flow type not repeated each year.

Recommended monitoring sites	Variable	Monitoring frequency
	Macroinvertebrates: Standard EPA Rapid Bioassessment techniques	Sample as part of ongoing EPA monitoring programs.
	Fish: Various sampling techniques	Early summer every 3-5 years but will need to be done more frequently if trying to detect responses to specific flow releases such as spring freshes.
Antwerp * EPA Site IIV, Anderson & Morison	Water Quality: Measure DO, EC, pH, temp at surface and depth in pools	Monthly Additional event monitoring to assess changes after freshes
	Hydrology: Visually assess flow and habitat inundation	During flow events Only needs to be done once for each flow type not repeated each year.
	Macroinvertebrates: Standard EPA Rapid Bioassessment techniques	Sample as part of ongoing EPA monitoring programs.
	Fish: Various sampling techniques	Early summer every 3-5 years but will need to be done more frequently if trying to detect responses to specific flow releases such as spring freshes.
Tarranyurk * (Tarranyark West Rd) Mitchell & Lind site, Anderson & Morrison site.	Water Quality: Measure DO, EC, pH, temp at surface and depth in pools	Monthly Additional event monitoring to assess changes after freshes Consider installing continuous EC and DO monitors at this site

Recommended monitoring sites	Variable	Monitoring frequency
	Hydrology: Visually assess flow and habitat inundation	During flow events Only needs to be done once for each flow type not repeated each year.
	Fish: Various sampling techniques	Early summer every 3-5 years but will need to be done more frequently if trying to detect responses to specific flow releases such as spring freshes.
MacKenzie River: Mount Zero Channel to Distribution Heads		
KEY SITE: Wartook: Grampians – Mt Victory Rd. SKM cross section	Water Quality: Measure DO, EC, pH, temp at surface and depth in pools	Monthly Additional event monitoring to assess changes after freshes
	Hydrology: Measure discharge and water levels Visually assess flow and habitat inundation	During flow events Only needs to be done once for each flow type not repeated each year.
	Geomorphology: Measure pool dimensions, sediment deposition, distribution of debris (photo points and/or direct measurement may be used)	Short term responses measure before and after specific flow events. Only needs to be done once for each flow type
	Geomorphology: Measure channel cross sections and longitudinal sections, vegetation extent and vegetation composition.	Every 3-5 years but should always be done in summer to accurately measure vegetation.

Recommended monitoring sites	Variable	Monitoring frequency
	Macroinvertebrates: Standard EPA Rapid Bioassessment techniques	Autumn & Spring every 3-5 years
	Fish: Various sampling techniques	Early summer every 3-5 years but will need to be done more frequently if trying to detect responses to specific flow releases such as spring freshes.
KEY SITE: Tatlocks Bridge **(Brimpaen – Laharum Rd)** EPA site IIP	Water Quality: Measure DO, EC, pH, temp at surface and depth in pools	Monthly Additional event monitoring to assess changes after freshes

Recommended monitoring sites	Variable	Monitoring frequency
	Hydrology: Measure discharge and water levels Visually assess flow and habitat inundation	During flow events Only needs to be done once for each flow type not repeated each year.
	Geomorphology: Measure pool dimensions, sediment deposition, distribution of debris (photo points and/or direct measurement may be used)	Short term responses measure before and after specific flow events. Only needs to be done once for each flow type
	Geomorphology: Measure channel cross sections and longitudinal sections, vegetation extent and vegetation composition.	Every 3-5 years but should always be done in summer to accurately measure vegetation.
	Macroinvertebrates: Standard EPA Rapid Bioassessment techniques	Autumn & Spring every 3-5 years
	Fish: Various sampling techniques	Early summer every 3-5 years but will need to be done more frequently if trying to detect responses to specific flow releases such as spring freshes.
MacKenzie River: Distribution Heads to Toolondo Channel		
KEY SITE: Grahams Bridge Road EPA site IIJ	Water Quality: Measure DO, EC, pH, temp at surface and depth in pools	Monthly Additional event monitoring to assess changes after freshes
	Hydrology: Measure discharge and water levels Visually assess flow and habitat inundation	During flow events Only needs to be done once for each flow type not repeated each year.
	Geomorphology: Measure pool dimensions, sediment deposition, distribution of debris (photo points and/or direct measurement may be used)	Short term responses measure before and after specific flow events. Only needs to be done once for each flow type

Recommended monitoring sites	Variable	Monitoring frequency
	Geomorphology: Measure channel cross sections and longitudinal sections, vegetation extent and vegetation composition.	Every 3-5 years but should always be done in summer to accurately measure vegetation.
	Macroinvertebrates: Standard EPA Rapid Bioassessment techniques	Autumn & Spring every 3-5 years
	Fish: Various sampling techniques	Early summer every 3-5 years but will need to be done more frequently if trying to detect responses to specific flow releases such as spring freshes.
KEY SITE: Hickeys Road No Data	Water Quality: Measure DO, EC, pH, temp at surface and depth in pools	Monthly Additional event monitoring to assess changes after freshes

Recommended monitoring sites	Variable	Monitoring frequency
	Hydrology: Measure discharge and water levels Visually assess flow and habitat inundation	During flow events Only needs to be done once for each flow type not repeated each year.
	Geomorphology: Measure pool dimensions, sediment deposition, distribution of debris (photo points and/or direct measurement may be used)	Short term responses measure before and after specific flow events. Only needs to be done once for each flow type
	Geomorphology: Measure channel cross sections and longitudinal sections, vegetation extent and vegetation composition.	Every 3-5 years but should always be done in summer to accurately measure vegetation.
	Macroinvertebrates: Standard EPA Rapid Bioassessment techniques	Autumn & Spring every 3-5 years
	Fish: Various sampling techniques	Early summer every 3-5 years but will need to be done more frequently if trying to detect responses to specific flow releases such as spring freshes.
MacKenzie River: Toolondo Channel to Wimmera River		
KEY SITE: Upstream of Wonwandah Rd SKM cross section	Water Quality: Measure DO, EC, pH, temp at surface and depth in pools	Monthly Additional event monitoring to assess changes after freshes
	Hydrology: Measure discharge and water levels Visually assess flow and habitat inundation	During flow events Only needs to be done once for each flow type not repeated each year.
	Geomorphology: Measure pool dimensions, sediment deposition, distribution of debris (photo points and/or direct measurement may be used)	Short term responses measure before and after specific flow events. Only needs to be done once for each flow type

Recommended monitoring sites	Variable	Monitoring frequency
	Geomorphology: Measure channel cross sections and longitudinal sections, vegetation extent and vegetation composition.	Every 3-5 years but should always be done in summer to accurately measure vegetation.
	Macroinvertebrates: Standard EPA Rapid Bioassessment techniques	Autumn & Spring every 3-5 years
	Fish: Various sampling techniques	Early summer every 3-5 years but will need to be done more frequently if trying to detect responses to specific flow releases such as spring freshes.
KEY SITE: Henty Highway at MacKenzie Creek VWQMN site 415251 & EPA site IHH reference site	Water Quality: Measure DO, EC, pH, temp at surface and depth in pools	Monthly Additional event monitoring to assess changes after freshes

Recommended monitoring sites	Variable	Monitoring frequency
	Hydrology: Measure discharge and water levels Visually assess flow and habitat inundation	During flow events Only needs to be done once for each flow type not repeated each year.
	Geomorphology: Measure pool dimensions, sediment deposition, distribution of debris (photo points and/or direct measurement may be used)	Short term responses measure before and after specific flow events. Only needs to be done once for each flow type
	Geomorphology: Measure channel cross sections and longitudinal sections, vegetation extent and vegetation composition.	Every 3-5 years but should always be done in summer to accurately measure vegetation.
	Macroinvertebrates: Standard EPA Rapid Bioassessment techniques	Autumn & Spring every 3-5 years
	Fish: Various sampling techniques	Early summer every 3-5 years but will need to be done more frequently if trying to detect responses to specific flow releases such as spring freshes.
Mount William Creek: Downstream of Lake Lonsdale		
KEY SITE: Western Hwy – Dadswells Bridge SKM cross section & EPA site IHV	Water Quality: Measure DO, EC, pH, temp at surface and depth in pools	Monthly Additional event monitoring to assess changes after freshes
	Hydrology: Measure discharge and water levels Visually assess flow and habitat inundation	During flow events Only needs to be done once for each flow type not repeated each year.
	Geomorphology: Measure pool dimensions, sediment deposition, distribution of debris (photo points and/or direct measurement may be used)	Short term responses measure before and after specific flow events. Only needs to be done once for each flow type

Recommended monitoring sites	Variable	Monitoring frequency
	Geomorphology: Measure channel cross sections and longitudinal sections, vegetation extent and vegetation composition.	Every 3-5 years but should always be done in summer to accurately measure vegetation.
	Macroinvertebrates: Standard EPA Rapid Bioassessment techniques	Autumn & Spring every 3-5 years
	Fish: Various sampling techniques	Early summer every 3-5 years but will need to be done more frequently if trying to detect responses to specific flow releases such as spring freshes.
KEY SITE: Morgans Bridge Glenorchy – Roses Gap Rd EPA site IHF reference site	Water Quality: Measure DO, EC, pH, temp at surface and depth in pools	Monthly Additional event monitoring to assess changes after freshes
	Hydrology: Measure discharge and water levels Visually assess flow and habitat inundation	During flow events Only needs to be done once for each flow type not repeated each year.
	Geomorphology: Measure pool dimensions, sediment deposition, distribution of debris (photo points and/or direct measurement may be used)	Short term responses measure before and after specific flow events. Only needs to be done once for each flow type
	Geomorphology: Measure channel cross sections and longitudinal sections, vegetation extent and vegetation composition.	Every 3-5 years but should always be done in summer to accurately measure vegetation.
	Macroinvertebrates: Standard EPA Rapid Bioassessment techniques	Autumn & Spring every 3-5 years
	Fish: Various sampling techniques	Early summer every 3-5 years but will need to be done more frequently if trying to detect responses to specific flow releases such as spring freshes.

Recommended monitoring sites	Variable	Monitoring frequency
Lake Lonsdale tail gauge VWQMN site 415203	Water Quality: Measure DO, EC, pH, temp at surface and depth in pools	Monthly Additional event monitoring to assess changes after freshes
	Hydrology: Measure discharge and water levels Visually assess flow and habitat inundation	During flow events Only needs to be done once for each flow type not repeated each year.
	Fish: Various sampling techniques	Early summer every 3-5 years but will need to be done more frequently if trying to detect responses to specific flow releases such as spring freshes.
Horsham - Wal Wal Rd No data	Water Quality: Measure DO, EC, pH, temp at surface and depth in pools	Monthly Additional event monitoring to assess changes after freshes
	Hydrology: Visually assess flow and habitat inundation	During flow events Only needs to be done once for each flow type not repeated each year.
	Fish: Various sampling techniques	Early summer every 3-5 years but will need to be done more frequently if trying to detect responses to specific flow releases such as spring freshes.
Crutes Rd No data	Water Quality: Measure DO, EC, pH, temp at surface and depth in pools	Monthly Additional event monitoring to assess changes after freshes

Recommended monitoring sites	Variable	Monitoring frequency
	Hydrology: Visually assess flow and habitat inundation	During flow events Only needs to be done once for each flow type not repeated each year.
	Fish: Various sampling techniques	Early summer every 3-5 years but will need to be done more frequently if trying to detect responses to specific flow releases such as spring freshes.
Burnt Creek: Distribution Heads to Toolondo Channel		
KEY SITE: U/S Laharum WonWondah East Rd SKM cross section	Water Quality: Measure DO, EC, pH, temp at surface and depth in pools	Monthly Additional event monitoring to assess changes after freshes
	Hydrology: Measure discharge and water levels Visually assess flow and habitat inundation	During flow events Only needs to be done once for each flow type not repeated each year.
	Geomorphology: Measure pool dimensions, sediment deposition, distribution of debris (photo points and/or direct measurement may be used)	Short term responses measure before and after specific flow events. Only needs to be done once for each flow type
	Geomorphology: Measure channel cross sections and longitudinal sections, vegetation extent and vegetation composition.	Every 3-5 years but should always be done in summer to accurately measure vegetation.
	Macroinvertebrates: Standard EPA Rapid Bioassessment techniques	Autumn & Spring every 3-5 years
	Fish: Various sampling techniques	Early summer every 3-5 years but will need to be done more frequently if trying to detect responses to specific flow releases such as spring freshes.

Recommended monitoring sites	Variable	Monitoring frequency
KEY SITE: Franciscos Rd No data	Water Quality: Measure DO, EC, pH, temp at surface and depth in pools	Monthly Additional event monitoring to assess changes after freshes
	Hydrology: Measure discharge and water levels Visually assess flow and habitat inundation	During flow events Only needs to be done once for each flow type not repeated each year.
	Geomorphology: Measure pool dimensions, sediment deposition, distribution of debris (photo points and/or direct measurement may be used)	Short term responses measure before and after specific flow events. Only needs to be done once for each flow type
	Geomorphology: Measure channel cross sections and longitudinal sections, vegetation extent and vegetation composition.	Every 3-5 years but should always be done in summer to accurately measure vegetation.
	Macroinvertebrates: Standard EPA Rapid Bioassessment techniques	Autumn & Spring every 3-5 years
	Fish: Various sampling techniques	Early summer every 3-5 years but will need to be done more frequently if trying to detect responses to specific flow releases such as spring freshes.
Burnt Creek: Downstream of Toolondo Channel		
KEY SITE: D/S Laharum WonWondah East Rd SKM Cross Section	Water Quality: Measure DO, EC, pH, temp at surface and depth in pools	Monthly Additional event monitoring to assess changes after freshes
	Hydrology: Measure discharge and water levels Visually assess flow and habitat inundation	During flow events Only needs to be done once for each flow type not repeated each year.

Recommended monitoring sites	Variable	Monitoring frequency
	Geomorphology: Measure pool dimensions, sediment deposition, distribution of debris (photo points and/or direct measurement may be used)	Short term responses measure before and after specific flow events. Only needs to be done once for each flow type
	Geomorphology: Measure channel cross sections and longitudinal sections, vegetation extent and vegetation composition.	Every 3-5 years but should always be done in summer to accurately measure vegetation.
	Macroinvertebrates: Standard EPA Rapid Bioassessment techniques	Autumn & Spring every 3-5 years
	Fish: Various sampling techniques	Early summer every 3-5 years but will need to be done more frequently if trying to detect responses to specific flow releases such as spring freshes.
KEY SITE: Western Hwy No data	Water Quality: Measure DO, EC, pH, temp at surface and depth in pools	Monthly Additional event monitoring to assess changes after freshes
	Hydrology: Measure discharge and water levels Visually assess flow and habitat inundation	During flow events Only needs to be done once for each flow type not repeated each year.
	Geomorphology: Measure pool dimensions, sediment deposition, distribution of debris (photo points and/or direct measurement may be used)	Short term responses measure before and after specific flow events. Only needs to be done once for each flow type
	Geomorphology: Measure channel cross sections and longitudinal sections, vegetation extent and vegetation composition.	Every 3-5 years but should always be done in summer to accurately measure vegetation.
	Macroinvertebrates: Standard EPA Rapid Bioassessment techniques	Autumn & Spring every 3-5 years

Recommended monitoring sites	Variable	Monitoring frequency
	Fish: Various sampling techniques	Early summer every 3-5 years but will need to be done more frequently if trying to detect responses to specific flow releases such as spring freshes.
Reynolds Rd No data	Water Quality: Measure DO, EC, pH, temp at surface and depth in pools	Monthly Additional event monitoring to assess changes after freshes
	Hydrology: Visually assess flow and habitat inundation	During flow events Only needs to be done once for each flow type not repeated each year.
	Fish: Various sampling techniques	Early summer every 3-5 years but will need to be done more frequently if trying to detect responses to specific flow releases such as spring freshes.
Glenelg River: Upstream of Rocklands Reservoir		
KEY SITE: Big Cord SKM Cross section, VWQMN site 238231 & EPA site JIH	Water Quality: Measure DO, EC, pH, temp at surface and depth in pools	Monthly Additional event monitoring to assess changes after freshes
	Hydrology: Measure discharge and water levels Visually assess flow and habitat inundation	During flow events Only needs to be done once for each flow type not repeated each year.
	Geomorphology: Measure pool dimensions, sediment deposition, distribution of debris (photo points and/or direct measurement may be used)	Short term responses measure before and after specific flow events. Only needs to be done once for each flow type
	Geomorphology: Measure channel cross sections and longitudinal sections, vegetation extent and vegetation composition.	Every 3-5 years but should always be done in summer to accurately measure vegetation.

Recommended monitoring sites	Variable	Monitoring frequency
	Macroinvertebrates: Standard EPA Rapid Bioassessment techniques	Autumn & Spring every 3-5 years
	Fish: Various sampling techniques	Early summer every 3-5 years but will need to be done more frequently if trying to detect responses to specific flow releases such as spring freshes.
KEY SITE: Henty Hwy No Data	Water Quality: Measure DO, EC, pH, temp at surface and depth in pools	Monthly Additional event monitoring to assess changes after freshes
	Hydrology: Measure discharge and water levels Visually assess flow and habitat inundation	During flow events Only needs to be done once for each flow type not repeated each year.
	Geomorphology: Measure pool dimensions, sediment deposition, distribution of debris (photo points and/or direct measurement may be used)	Short term responses measure before and after specific flow events. Only needs to be done once for each flow type
	Geomorphology: Measure channel cross sections and longitudinal sections, vegetation extent and vegetation composition.	Every 3-5 years but should always be done in summer to accurately measure vegetation.
	Macroinvertebrates: Standard EPA Rapid Bioassessment techniques	Autumn & Spring every 3-5 years
	Fish: Various sampling techniques	Early summer every 3-5 years but will need to be done more frequently if trying to detect responses to specific flow releases such as spring freshes.
Red Hill Road EPA site JII (this site unlikely to be affected by abstraction but may be used as a reference)	Water Quality: Measure DO, EC, pH, temp at surface and depth in pools	Monthly Additional event monitoring to assess changes after freshes

Recommended monitoring sites	Variable	Monitoring frequency
	Hydrology: Visually assess flow and habitat inundation	During flow events Only needs to be done once for each flow type not repeated each year.
	Macroinvertebrates: Standard EPA Rapid Bioassessment techniques	Sample as part of ongoing EPA monitoring programs.
	Fish: Various sampling techniques	Early summer every 3-5 years but will need to be done more frequently if trying to detect responses to specific flow releases such as spring freshes.
Glenisla Crossing Rd No data	Water Quality: Measure DO, EC, pH, temp at surface and depth in pools	Monthly Additional event monitoring to assess changes after freshes
	Hydrology: Visually assess flow and habitat inundation	During flow events Only needs to be done once for each flow type not repeated each year.
	Fish: Various sampling techniques	Early summer every 3-5 years but will need to be done more frequently if trying to detect responses to specific flow releases such as spring freshes.
Syphon Rd No data	Water Quality: Measure DO, EC, pH, temp at surface and depth in pools	Monthly Additional event monitoring to assess changes after freshes

Recommended monitoring sites	Variable	Monitoring frequency
	Hydrology: Visually assess flow and habitat inundation	During flow events Only needs to be done once for each flow type not repeated each year.
	Fish: Various sampling techniques	Early summer every 3-5 years but will need to be done more frequently if trying to detect responses to specific flow releases such as spring freshes.
Glenelg River: Rocklands Reservoir to Chetwynd River		
KEY SITE: Harrow SKM cross section at pump station, EPA site JJM	Water Quality: Measure DO, EC, pH, temp at surface and depth in pools	Monthly Additional event monitoring to assess changes after freshes
	Hydrology: Measure discharge and water levels Visually assess flow and habitat inundation	During flow events Only needs to be done once for each flow type not repeated each year.
	Geomorphology: Measure pool dimensions, sediment deposition, distribution of debris (photo points and/or direct measurement may be used)	Short term responses measure before and after specific flow events. Only needs to be done once for each flow type
	Geomorphology: Measure channel cross sections and longitudinal sections, vegetation extent and vegetation composition.	Every 3-5 years but should always be done in summer to accurately measure vegetation.
	Macroinvertebrates: Standard EPA Rapid Bioassessment techniques	Autumn & Spring every 3-5 years
	Fish: Various sampling techniques	Early summer every 3-5 years but will need to be done more frequently if trying to detect responses to specific flow releases such as spring freshes.
KEY SITE: Pine Hut Hole SKM cross section, Mitchell & Lind Study	Water Quality: Measure DO, EC, pH, temp at surface and depth in pools	Monthly Additional event monitoring to assess changes after freshes

Recommended monitoring sites	Variable	Monitoring frequency
	Hydrology: Measure discharge and water levels Visually assess flow and habitat inundation	During flow events Only needs to be done once for each flow type not repeated each year.
	Geomorphology: Measure pool dimensions, sediment deposition, distribution of debris (photo points and/or direct measurement may be used)	Short term responses measure before and after specific flow events. Only needs to be done once for each flow type
	Geomorphology: Measure channel cross sections and longitudinal sections, vegetation extent and vegetation composition.	Every 3-5 years but should always be done in summer to accurately measure vegetation.
	Macroinvertebrates: Standard EPA Rapid Bioassessment techniques	Autumn & Spring every 3-5 years
	Fish: Various sampling techniques	Early summer every 3-5 years but will need to be done more frequently if trying to detect responses to specific flow releases such as spring freshes.
Dick Roberts Property SKM cross section	Water Quality: Measure DO, EC, pH, temp at surface and depth in pools	Monthly Additional event monitoring to assess changes after freshes
	Hydrology: Measure discharge and water levels Visually assess flow and habitat inundation	During flow events Only needs to be done once for each flow type not repeated each year.
	Fish: Various sampling techniques	Early summer every 3-5 years but will need to be done more frequently if trying to detect responses to specific flow releases such as spring freshes.
Five Mile outfall * SKM cross section	Water Quality: Measure DO, EC, pH, temp at surface and depth in pools	Monthly Additional event monitoring to assess changes after freshes

Recommended monitoring sites	Variable	Monitoring frequency
	Hydrology: Visually assess flow and habitat inundation	During flow events Only needs to be done once for each flow type not repeated each year.
	Fish: Various sampling techniques	Early summer every 3-5 years but will need to be done more frequently if trying to detect responses to specific flow releases such as spring freshes.
Rocklands Reservoir * VWQMN site 238205	Water Quality: Measure DO, EC, pH, temp at surface and depth in pools	Monthly Additional event monitoring to assess changes after freshes
	Hydrology: Measure discharge and water levels Visually assess flow and habitat inundation	During flow events Only needs to be done once for each flow type not repeated each year.
	Fish: Various sampling techniques	Early summer every 3-5 years but will need to be done more frequently if trying to detect responses to specific flow releases such as spring freshes.
Fulham Bridge VWQMN site 238224, EPA reference site JIJ, Mitchell and Lind	Water Quality: Measure DO, EC, pH, temp at surface and depth in pools	Monthly Additional event monitoring to assess changes after freshes
	Hydrology: Measure discharge and water levels Visually assess flow and habitat inundation	During flow events Only needs to be done once for each flow type not repeated each year.
	Macroinvertebrates: Standard EPA Rapid Bioassessment techniques	Sample as part of ongoing EPA monitoring programs.
	Fish: Various sampling techniques	Early summer every 3-5 years but will need to be done more frequently if trying to detect responses to specific flow releases such as spring freshes.

Recommended monitoring sites	Variable	Monitoring frequency
Balmoral * (Rocklands Road) Mitchell and Lind	Water Quality: Measure DO, EC, pH, temp at surface and depth in pools	Monthly Additional event monitoring to assess changes after freshes
	Hydrology: Visually assess flow and habitat inundation	During flow events Only needs to be done once for each flow type not repeated each year.
	Fish: Various sampling techniques	Early summer every 3-5 years but will need to be done more frequently if trying to detect responses to specific flow releases such as spring freshes.
Mooree - Connewirrecoo Rd EPA site JIX	Water Quality: Measure DO, EC, pH, temp at surface and depth in pools	Monthly Additional event monitoring to assess changes after freshes
	Hydrology: Visually assess flow and habitat inundation	During flow events Only needs to be done once for each flow type not repeated each year.
	Macroinvertebrates: Standard EPA Rapid Bioassessment techniques	Sample as part of ongoing EPA monitoring programs.
	Fish: Various sampling techniques	Early summer every 3-5 years but will need to be done more frequently if trying to detect responses to specific flow releases such as spring freshes.
Glenelg River: Chetwynd River to Wannon River		
KEY SITE: Burkes Bridge (Casterton – Edenhope Rd) SKM cross section, EPA site JJN, Mitchell and Lind	Water Quality: Measure DO, EC, pH, temp at surface and depth in pools	Monthly Additional event monitoring to assess changes after freshes
	Hydrology: Measure discharge and water levels Visually assess flow and habitat inundation	During flow events Only needs to be done once for each flow type not repeated each year.

Recommended monitoring sites	Variable	Monitoring frequency
	Geomorphology: Measure pool dimensions, sediment deposition, distribution of debris (photo points and/or direct measurement may be used)	Short term responses measure before and after specific flow events. Only needs to be done once for each flow type
	Geomorphology: Measure channel cross sections and longitudinal sections, vegetation extent and vegetation composition.	Every 3-5 years but should always be done in summer to accurately measure vegetation.
	Macroinvertebrates: Standard EPA Rapid Bioassessment techniques	Autumn & Spring every 3-5 years
	Fish: Various sampling techniques	Early summer every 3-5 years but will need to be done more frequently if trying to detect responses to specific flow releases such as spring freshes.
KEY SITE: Section Road SKM cross section	Water Quality: Measure DO, EC, pH, temp at surface and depth in pools	Monthly Additional event monitoring to assess changes after freshes
	Hydrology: Measure discharge and water levels Visually assess flow and habitat inundation	During flow events Only needs to be done once for each flow type not repeated each year.
	Geomorphology: Measure pool dimensions, sediment deposition, distribution of debris (photo points and/or direct measurement may be used)	Short term responses measure before and after specific flow events. Only needs to be done once for each flow type
	Geomorphology: Measure channel cross sections and longitudinal sections, vegetation extent and vegetation composition.	Every 3-5 years but should always be done in summer to accurately measure vegetation.
	Macroinvertebrates: Standard EPA Rapid Bioassessment techniques	Autumn & Spring every 3-5 years

Recommended monitoring sites	Variable	Monitoring frequency
	Fish: Various sampling techniques	Early summer every 3-5 years but will need to be done more frequently if trying to detect responses to specific flow releases such as spring freshes.
200m us Warrock Rd Bridge SKM cross section	Water Quality: Measure DO, EC, pH, temp at surface and depth in pools	Monthly Additional event monitoring to assess changes after freshes
	Hydrology: Measure discharge and water levels Visually assess flow and habitat inundation	During flow events Only needs to be done once for each flow type not repeated each year.
	Fish: Various sampling techniques	Early summer every 3-5 years but will need to be done more frequently if trying to detect responses to specific flow releases such as spring freshes.
Dergholm – Chetwynd Rd EPA reference site JIG	Water Quality: Measure DO, EC, pH, temp at surface and depth in pools	Monthly Additional event monitoring to assess changes after freshes
	Hydrology: Visually assess flow and habitat inundation	During flow events Only needs to be done once for each flow type not repeated each year.
	Macroinvertebrates: Standard EPA Rapid Bioassessment techniques	Sample as part of ongoing EPA monitoring programs.
	Fish: Various sampling techniques	Early summer every 3-5 years but will need to be done more frequently if trying to detect responses to specific flow releases such as spring freshes.
Casterton – Naracoorte Rd EPA site JIR	Water Quality: Measure DO, EC, pH, temp at surface and depth in pools	Monthly Additional event monitoring to assess changes after freshes

Recommended monitoring sites	Variable	Monitoring frequency
	Hydrology: Visually assess flow and habitat inundation	During flow events Only needs to be done once for each flow type not repeated each year.
	Macroinvertebrates: Standard EPA Rapid Bioassessment techniques	Sample as part of ongoing EPA monitoring programs.
	Fish: Various sampling techniques	Early summer every 3-5 years but will need to be done more frequently if trying to detect responses to specific flow releases such as spring freshes.
Glenelg River: Wannon River to Dartmoor		
KEY SITE: Sandford (ds Bahgallah Rd Bridge) SKM cross section, VWQMN site 238202, EPA site JIP	Water Quality: Measure DO, EC, pH, temp at surface and depth in pools	Monthly Additional event monitoring to assess changes after freshes
	Hydrology: Measure discharge and water levels Visually assess flow and habitat inundation	During flow events Only needs to be done once for each flow type not repeated each year.
	Geomorphology: Measure pool dimensions, sediment deposition, distribution of debris (photo points and/or direct measurement may be used)	Short term responses measure before and after specific flow events. Only needs to be done once for each flow type
	Geomorphology: Measure channel cross sections and longitudinal sections, vegetation extent and vegetation composition.	Every 3-5 years but should always be done in summer to accurately measure vegetation.
	Macroinvertebrates: Standard EPA Rapid Bioassessment techniques	Autumn & Spring every 3-5 years

Recommended monitoring sites	Variable	Monitoring frequency
	Fish: Various sampling techniques	Early summer every 3-5 years but will need to be done more frequently if trying to detect responses to specific flow releases such as spring freshes.
KEY SITE: Dartmoor (streamside reserve us Greenham Rd) SKM cross section, VWQMN site 238206, EPA reference site JIE	Water Quality: Measure DO, EC, pH, temp at surface and depth in pools	Monthly Additional event monitoring to assess changes after freshes
	Hydrology: Measure discharge and water levels Visually assess flow and habitat inundation	During flow events Only needs to be done once for each flow type not repeated each year.
	Geomorphology: Measure pool dimensions, sediment deposition, distribution of debris (photo points and/or direct measurement may be used)	Short term responses measure before and after specific flow events. Only needs to be done once for each flow type
	Geomorphology: Measure channel cross sections and longitudinal sections, vegetation extent and vegetation composition.	Every 3-5 years but should always be done in summer to accurately measure vegetation.
	Macroinvertebrates: Standard EPA Rapid Bioassessment techniques	Autumn & Spring every 3-5 years
	Fish: Various sampling techniques	Early summer every 3-5 years but will need to be done more frequently if trying to detect responses to specific flow releases such as spring freshes.
Killara (Casterton – Dartmoor Rd) EPA reference site JIC	Water Quality: Measure DO, EC, pH, temp at surface and depth in pools	Monthly Additional event monitoring to assess changes after freshes
	Hydrology: Visually assess flow and habitat inundation	During flow events Only needs to be done once for each flow type not repeated each year.

Recommended monitoring sites	Variable	Monitoring frequency
	Macroinvertebrates: Standard EPA Rapid Bioassessment techniques	Sample as part of ongoing EPA monitoring programs.
	Fish: Various sampling techniques	Early summer every 3-5 years but will need to be done more frequently if trying to detect responses to specific flow releases such as spring freshes.
Myaring – Pieracle Rd No Data	Water Quality: Measure DO, EC, pH, temp at surface and depth in pools	Monthly Additional event monitoring to assess changes after freshes
	Hydrology: Visually assess flow and habitat inundation	During flow events Only needs to be done once for each flow type not repeated each year.
	Fish: Various sampling techniques	Early summer every 3-5 years but will need to be done more frequently if trying to detect responses to specific flow releases such as spring freshes.
School Rd Wilkin No Data	Water Quality: Measure DO, EC, pH, temp at surface and depth in pools	Monthly Additional event monitoring to assess changes after freshes

Recommended monitoring sites	Variable	Monitoring frequency
	Hydrology: Visually assess flow and habitat inundation	During flow events Only needs to be done once for each flow type not repeated each year.
	Fish: Various sampling techniques	Early summer every 3-5 years but will need to be done more frequently if trying to detect responses to specific flow releases such as spring freshes.
Wannon River: Upper reaches		
KEY SITE: First Wannon Creek downstream of weir SKM assessment site but no cross section data	Water Quality: Measure DO, EC, pH, temp at surface and depth in pools	Monthly Additional event monitoring to assess changes after freshes
	Hydrology: Measure discharge and water levels Visually assess flow and habitat inundation	During flow events Only needs to be done once for each flow type not repeated each year.
	Geomorphology: Measure pool dimensions, sediment deposition, distribution of debris (photo points and/or direct measurement may be used)	Short term responses measure before and after specific flow events. Only needs to be done once for each flow type
	Geomorphology: Measure channel cross sections and longitudinal sections, vegetation extent and vegetation composition.	Every 3-5 years but should always be done in summer to accurately measure vegetation.
	Macroinvertebrates: Standard EPA Rapid Bioassessment techniques	Autumn & Spring every 3-5 years
	Fish: Various sampling techniques	Early summer every 3-5 years but will need to be done more frequently if trying to detect responses to specific flow releases such as spring freshes.

Recommended monitoring sites	Variable	Monitoring frequency
KEY SITE: Second Wannon Creek downstream of weir SKM assessment site but no cross section data	Water Quality: Measure DO, EC, pH, temp at surface and depth in pools	Monthly Additional event monitoring to assess changes after freshes
	Hydrology: Measure discharge and water levels Visually assess flow and habitat inundation	During flow events Only needs to be done once for each flow type not repeated each year.
	Geomorphology: Measure pool dimensions, sediment deposition, distribution of debris (photo points and/or direct measurement may be used)	Short term responses measure before and after specific flow events. Only needs to be done once for each flow type
	Geomorphology: Measure channel cross sections and longitudinal sections, vegetation extent and vegetation composition.	Every 3-5 years but should always be done in summer to accurately measure vegetation.
	Macroinvertebrates: Standard EPA Rapid Bioassessment techniques	Autumn & Spring every 3-5 years
	Fish: Various sampling techniques	Early summer every 3-5 years but will need to be done more frequently if trying to detect responses to specific flow releases such as spring freshes.
Wannon River at Jimmy Creek VWQMN site 238207	Water Quality: Measure DO, EC, pH, temp at surface and depth in pools	Monthly Additional event monitoring to assess changes after freshes
	Hydrology: Measure discharge and water levels Visually assess flow and habitat inundation	During flow events Only needs to be done once for each flow type not repeated each year.
	Fish: Various sampling techniques	Early summer every 3-5 years but will need to be done more frequently if trying to detect responses to specific flow releases such as spring freshes.