NORTH EAST CATCHMENT MANAGEMENT AUTHORITY

FINAL RECOMMENDATIONS PAPER

ENVIRONMENTAL FLOW DETERMINATION FOR THE KIEWA RIVER

EarthTech

Environmental Flow Determination for the Kiewa

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Document History:

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The Kiewa River Environmental Water Requirements Technical Panel (the Technical Panel) consists of (with fields of expertise):

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Stafford Simpson	VRFish
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Acronyms/Abbreviations Used in this report:

ARI	Annual Recurrence Interval
BE	Bulk water Entitlements
CMA	Catchment Management Authority
DNRE	Department of Natural Resources and Environment
DSE	Department of Sustainability and Environment
EVC	Ecological Vegetation Class
Expert Panel	The Kiewa River Environmental Water Requirements Expert Panel
FLOWS	The "State-wide Method for Determining Environmental Water Requirements"
ISC	Index of Stream Condition
SFMP	Streamflow Management Plan
VRHS	Victorian River Health Strategy

Definitions

Flow components used in this report and their descriptions are provided below together with a graphical representation of the components in Figure A.

Low Flow	Flow that generally provides a continuous flow through the channel.
Low Flow Freshes	Small and short duration peak flow events that exceed the baseflow (low flow) and last for at least several days. Usually in summer and autumn in Victoria.
High Flow	Persistent increases in the seasonal baseflow that remain within the channel.
High Flow Freshes	Small and short duration peak flow events that exceed the high flow and last for at least several days. Usually in winter and spring in Victoria.
Bankfull Flow	Completely fills the channel, with little flow spilling onto the floodplain.
Overbank flows	These flows are greater than bankfull discharge and result in surface flow on the floodplain habitats.

Figure 1-1 Hydrograph showing Flow components required to maintain a healthy ecosystem (DSE, 2006)

Scientific terms used within this report include:

Amphibious	Capable of dwelling on dry land as well as in water.
Anabranch	A river channel in an anabranching network of river channels (see below).
Anabranching	An anabranching river is a pattern of multiple channels separated by vegetated or otherwise stable islands or ridges. These islands or ridges are large relative to the size of the river channels and generally extend to bankfull height.
Average Recurrence Interval (ARI)	The long-term average number of years between the occurrence of a given flow. For example, a flow with an average recurrence interval of 20 years will, on average, occur once every 20 years.
Backwater	A small, generally shallow body of water attached to the main channel, with little or no current of its own
Bankfull	Completely fills the channel, with little flow spilling onto the floodplain.
Baseflow	The component of streamflow that is supplied by the discharge of groundwater.
Bed load	The material carried on or close to the stream bed by water through rolling, sliding and bouncing as it is too heavy to be carried in suspension.

Bench	Distinctly stepped, elongate, straight to gently curved feature that is inset along one or both banks. A major in channel sediment storage unit often positioned on top of bar deposits.
Benthic zone	The lowest level of water in a stream which is inhabited by benthic organisms that live in close relationship with the ground.
Biofilm	A microscopic assemblage of algae, fungi, bacteria and unicellular animals in a matrix of organic compounds.
Bryophyte	Spore producing plants including the mosses, liverworts and hornworts.
Catchment	An area of land where run-off generated from rainfall flows into one river system.
Cease-to-flow	No discernible flow in the river or no flow recorded at a gauge.
Colluvial deposits	Material that has been transported downhill by gravity rather than stream (fluvial) processes such as mass-wasting and local un-concentrated runoff. Colluvial deposits accumulate on lower slopes and/or at the bottom of the hill.
Colluvial fan	A fan shaped deposit formed by non-fluvial processes.
Confined (channel)	River channel runs through a valley with no significant floodplain on either side such that the channel is unable to migrate laterally.
Degradation	The process by which the slope of a stream is reduced by the removal of sediment from the stream bed through erosion.
Ecological Vegetation Class (EVC)	An EVC is part of a detailed classification system for native vegetation, which is described through a collection of floristic, life form and ecological characteristics and inferred fidelity to particular environmental attributes. Each EVC includes a combination of floristic communities that occur across a biogeographic range, and although differing in species, have similar habitat and ecological processes occurring.
Environmental flow	The streamflow that is needed to sustain and where necessary restore ecological processes and biodiversity of water dependant ecosystems in a river.
Epilithic	Growing on rock.
Floodplain	The relatively flat valley floor found next to alluvial river channels that are inundated during larger flow events.
Floodplain pocket	A small section of floodplain located along a reach of river which is predominantly confined.
Gradational soils	Soils which gradually increase in texture (ie. clay content increases) as the profile deepens.
High flow	Persistent increases in the seasonal baseflow that remain within the channel.
High flow freshes	Small and short duration peak flow events that exceed the baseflow (high flow) and last for at least several days. Usually in winter and spring in Victoria.
High flow season	Is the period for which the hydrology of the Kiewa River is dominated by high flows, from June through to November.

Interstitial	Within the pores or between the grains of a rock
Lateral migration	The behaviour of a meandering stream as its course snakes from side to side undercutting the banks and moving sideways or laterally.
Laterally un-confined	A laterally un-confined channel has floodplain on both sides and is able to migrate laterally to the left and right
Levee	A raised embankment along the edge of a river channel. Natural levees result from periodic overbank flooding, when coarser sediment is immediately deposited because of a reduction in river velocity. Levees are often constructed by humans living in low-lying areas as protection against flooding.
Low flow	Flow that generally provides a continuous flow through the channel.
Low Flow Freshes	Small and short duration peak flow events that exceed the baseflow (low flow) and last for at least several days. Usually in summer and autumn in Victoria.
Low flow season	Is the period for which the hydrology of the Kiewa River is dominated by low flows, from December through to May.
Macrophyte	Non-woody wetland aquatic plants. Literally means 'large plant' (originally to distinguish from microphyte which was once used to refer to phytoplankton).
Overbank flows	These flows are greater than bankfull discharge and result in surface flow on the floodplain.
Piedmont	An area of shallow, rolling hills formed or lying at the foot of a mountain or mountain range.
Plan form	The outline and shape of a stream when viewed from directly overhead.
Reach	A length of stream channel that exhibits on average, relatively uniform characteristics (e.g. hydraulic properties, geomorphology, hydrology).
Recession	When the water level falls in a river.
Regulated	The flow of the river is regulated through the operation of large dams or weirs.
Rhizome	A horizontal stem with the ability to produce new clones of the same plant from buds at the nodes.
Rhizomatous	Bearing rhizomes (see previous).
Riffle	Shallow water flowing rapidly over stones and gravel.
Riparian	The area between terrestrial and aquatic environments, and transitional in character between these; the riparian zone is functionally part of the adjacent river. Riparian refers to the species, communities or vegetation growing in the riparian zone.
Ruderal	Robust, sturdy or vigorous plants. Plants that are able to inhabit disturbed sites (e.g. gravel bar).

Run	A stretch of uniform and relatively featureless bed that comprises bedrock, cobble or gravel. A smooth flow zone that is either free-flowing or an imposed shallow channel-link feature that connects pools.
Salicaceae	A family of deciduous trees and shrubs, originating mainly from the cool temperate regions of the northern hemisphere. The most significant for riparian ecology in Australia are species and hybrids in the genus *Populus*, commonly known as aspens, cottonwoods and poplars, and in the genus *Salix*, commonly known as willows, sallows and osiers.
Sedimentation	Process whereby solid particles in a stream sink to the bottom of the channel, forming a layer of sediment.
Shear stress	The lateral force applied to a surface per unit area. In this context the force per unit area that the flow of water applies to the channel boundaries of the river that, if high enough, cause erosion.
Terrace	A build-up of river deposits along the sides of a river valley, which were accumulated when bed levels were higher along the river. Older floodplain, which either no longer floods or rarely floods due to more contemporary deepening or enlargement of the stream channel.
Turbidity	The amount of solid particles which are suspended in water and causing light rays shining through the water to scatter. Turbidity makes the water in streams cloudy, or even opaque in extreme cases.
Vertical accretion	Accumulation of sediments or other material resulting in the building-up or infilling of an area in a vertical direction.

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Executive Summary

The North East Catchment Management Authority (NECMA) has commissioned Earth Tech to undertake an investigation to determine the environmental flow requirements of the Kiewa River catchment. The assessment has been undertaken in accordance with the FLOWS method – an established approach for the determination of environmental flows in Victoria (DNRE, 2002b). This report represents the final stage in the environmental flow determination of the Kiewa River, presenting the final flow recommendations. This study sits within the wider project of developing a Streamflow Management Plan for the Kiewa River.

The Kiewa River catchment is situated between the Ovens and Mitta Mitta River Basins and flows into the Murray River, downstream of Lake Hume. The catchment can be roughly divided into two main sections: the forested, mountainous upper catchment and a lower catchment, downstream of Mt Beauty, where agriculture is the primary land use. Hydroelectricity is generated in the Upper Kiewa River. There are no major impoundments for the purposes of water diversions. However, the impoundments do influence the hydrology of the Kiewa River slightly, increasing the magnitude of some flow events in summer by storing water in winter and spring. Major tributaries that have been directly involved in the development of flow recommendations are Mountain Creek, Running Creek and Yackandandah Creek.

In this study the environmental flow requirements have been determined for the Kiewa River below the Mount Beauty Pondage. For each of the flow requirements identified, the proportion of time the flow event occurs under the current and natural flow regimes is determined, this is referred to as the flow compliance. The change in flow compliance between the natural and current flow regimes gives an indication of the magnitude of anthropogenic impacts on each aspect of the hydrology important to environmental flow requirements. The scope for the report does not include analysis of impacts of the recommended flow regime or details of operational or infrastructure issues in relation to the implementation of environmental water requirements. Recommendations from this report will feed into the Streamflow Management Plan for the Kiewa River.

To facilitate the flow determination for the Kiewa River, six reaches were selected and one representative study site identified in each of the six reaches. The six study sites were used to identify environmental assets and, based on the vision for the reach, set key environmental objectives in order to determine the environmental flow requirements of the Kiewa River.

Environmental and flow objectives were developed for each reach to realise the maintenance, restoration and rehabilitation of the environmental assets of the Kiewa River identified by the Technical Panel. The environmental objectives have been developed only for those assets that depend on some aspect of the flow regime. The objectives of the environmental flow recommendations made in this report are for particular species and communities, habitats and ecological processes, and include the following:

- To maintain the flow components that facilitate the ongoing evolution of physical form and the ongoing recovery of geomorphic values from human-induced impacts;

- To maintain water depth over invertebrate habitat in riffles, pools and on snags;
- To maintain or improve water quality by providing adequate base flows and by providing flushing flows to remove accumulated sediment from rocks on the river bed;
- To restore self-sustaining populations of Murray Cod, Murray Crayfish, blackfish, Mountain galaxias and small-bodied native fish species associated with wetland habitats;
- Facilitate the return and/or persistence of native riparian vegetation in-channel, on banks and in the wider riparian zone; and
- Maintain wetland resilience (capacity to recover) through appropriate water and land management.

These objectives have been developed not only to maintain current conditions or environmental assets, such as threatened species, but also to maintain natural communities and ecological processes that are important for river health.

The objectives listed above set the direction and target for environmental flow recommendations and will guide future water resource management decisions. In particular, these objectives identify the environmental assets of the Kiewa River that are dependent on flow. These assets will be weighed against social and economic values in making future water resource management decisions.

This paper is the final report presenting the flow recommendations for the Kiewa River arising from the Technical Panel Workshop. The workshop included all members of the Technical Panel and represented the fields of geomorphology, hydraulics, vegetation, wetlands, fish, water quality and macroinvertebrates. A summary of the flow recommendations from this workshop is provided in Table A.

Overall the preliminary compliance calculations for the flow recommendations in Table A indicate that the current flow regime on the main stem of the Kiewa River may already provide for the environmental assets that are dependent on low flows, high flows and the smaller fresh events. However, the environmental assets dependent on the occurrence of larger freshes, bankfull and overbank events may, particularly in the upstream reaches, be impacted under the current flow regime.

In the tributaries of the Kiewa River, Mountain Creek, Running Creek and Yackandandah Creek, the preliminary compliance calculations indicate that the current flow regime may be little changed from natural. Hence, under current conditions the flow requirements of environmental assets in these tributaries may largely be met. The possible exception to this generalisation is the low flow recommendation for Running Creek where further diversions during the low flow season may start to impact on environmental assets.

Table A Summary of Flow Recommendations

<table>
<tr><th rowspan="2">Flow Component</th><th colspan="6">Reach</th></tr>
<tr><th>1</th><th>2</th><th>3</th><th>4</th><th>5</th><th>6</th></tr>
<tr><td>Low Flow (Dec - May)</td><td>259ML/d (or natural)</td><td>346ML/d (or natural)</td><td>432ML/d (or natural)</td><td>17ML/day (or natural)</td><td>26ML/d (or natural)</td><td>16ML/d (or natural)</td></tr>
<tr><td>Low Flow Fresh</td><td></td><td></td><td></td><td>130ML/d (1/season, 1d – or natural, Dec-Apr)</td><td>130ML/d (1/season, 1d – or natural, Dec-Apr)</td><td></td></tr>
<tr><td>High Flow (Jun-Nov)</td><td></td><td>1184ML/d (or natural)</td><td>1287ML/d (or natural)</td><td>58ML/d (or natural)</td><td>47ML/d (or natural)</td><td>65ML/d (or natural)</td></tr>
<tr><td rowspan="6">High Flow Fresh</td><td rowspan="6">8122ML/d (1/season, 1d – or natural, Jul-Nov)</td><td rowspan="6">3888ML/d (2/season, 3d – or natural, Jul-Sep)</td><td rowspan="6">2592ML/d (2/season, 3d – or natural, Jul-Sep)</td><td rowspan="6"></td><td>86ML/d – (80% of years, 35d – or natural, Sep-Nov)</td><td rowspan="2">346ML/d (3/season, 3d – or natural, Jun-Nov)</td></tr>
<tr><td>467ML/d (1/season, 2d – or natural, Jul-Nov)</td></tr>
<tr><td rowspan="2">518ML/d (1/2yrs, 1d – or natural, Jul-Sep)</td><td>346ML/d (2/season, 2d – or natural, Jul-Sep)</td></tr>
<tr><td>1904ML/d (1/season, 1d – or natural, Jul-Nov)</td></tr>
<tr><td>1123ML/d (1/3yrs, 2d – or natural, Jun-Nov)</td><td>1904ML/d (1/6yrs, 1d – or natural, Jun-Nov)</td></tr>
<tr><td>467ML/d (1/5yrs, 2d – or natural, Sep-Oct)</td><td>1904ML/d (1/5yrs, 1d – or natural, Sep-Oct)</td></tr>
</table>

Flow Component	Reach					
	1	2	3	4	5	6
Fresh (Jan-Dec)	6480ML/d (1/season, 1d – or natural)	1728ML/d (4/season, 4d – or natural)		147ML/d (3/season, 3d – or natural)	346ML/d (1/season, 3d – or natural)	259ML/d (3/season, 3d – or natural)
	8122ML/d (1/season, 1d – or natural)				518ML/d (1/season, 1d – or natural)	350ML/d (4/season, 2d – or natural)
	30240ML/d (1/20yrs, 1d – or natural)				1123ML/d (1/3 years, 1d – or natural)	1904ML/d (1/season, 1d – or natural)
Bankfull		6048ML/d (1/season, 3d – or natural, Jul-Sep)	3024ML/d (4/season, 4d – or natural, Jan-Dec)	173ML/d (2/season, 2d – or natural, Jan-Dec)		
		6912ML/d (1/season, 1d – or natural, Jan-Dec)	4320ML/d (1/season, 6d – or natural, Jul-Sep)			
Overbank		6912ML/d (1/season, 2d – or natural, Jun-Nov)	5184ML/d (1/5 years, 7d – or natural, Sep-Oct)	173ML/d (3/season, 2d – or natural, Jul-Nov)		
		6912ML/d (1/5years, 3d – or natural, Sep-Oct)	5184ML/d (2/season, 4d – or natural, Jun-Nov)	346ML/d (1/season, 1d – or natural, Jan-Dec)		
		6912ML/d (1/season, 2d – or natural, Jul-Dec)	5184ML/d (1/season, 4d – or natural, Jul-Dec)			
		6912ML/d (1/season, 2d – or natural, Jul-Nov)	4628ML/d (2/season, 4d – or natural, Jan-Dec)			
		5616L/d (2/season, 2d – or natural, Jan-Dec)				

Contents

1. Introduction

The North East CMA has engaged Earth Tech to undertake an assessment of environmental flow requirements for the Kiewa River catchment (refer to map in Appendix A). The assessment is being undertaken in accordance with the FLOWS method – an established approach for the determination of environmental flows in Victoria (DNRE, 2002).

The FLOWS method involves the collation and review of information through a number of sources including a literature review (Site Paper), field assessments, consultation with agencies and community members, topographic survey, hydraulic modelling and scientific panel discussions/workshop. This report (Recommendations Paper), represents the final stage in the environmental flow determination of the Kiewa River, presents flow recommendations. It is based on catchment knowledge identified in the Site Paper, flow objectives presented in the Issues Paper and hydraulic modelling undertaken in the Technical Panel Workshop held in Melbourne on Monday the 6th of August, 2007.

It is important to note that this environmental flow assessment does not directly address non-flow related issues impacting on river health and management. This includes issues that may be mitigated through the flow regime but ultimately, may be better dealt with at source. All non-flow related issues identified within the FLOWS process are mentioned within a chapter in this report which provides a list of possible complementary actions that will assist in achieving the visions for each study reach of the Kiewa Catchment.

The results of this environmental flow determination will feed into the Streamflow Management Plan for the Kiewa River, which will be developed following the completion of this Environmental Flow determination.

The FLOWS method assists in the identification of critical flow components, as part of the total flow regime, to protect, sustain or restore specific flow dependent assets or values. The key elements of the flows process include:

- An objective setting process that links environmental objectives to flow objectives and recommendations;
- The use of an Expert Panel to determine environmental flows; and
- The use of hydrologic and hydraulic analysis tools in the interpretation and development of recommendations (DNRE, 2002).

This Recommendations Report has been developed following the production of a Site Paper and Issues Paper and forms part of the FLOWS method (Figure 2). The Site Paper (Earth Tech, 2007b) provides background information on the Kiewa River including a catchment description, details of historic land use, water use, broad condition descriptions and recommended reaches for the investigations. Reach visions, environmental objectives and the flow criteria to achieve the objectives are set out in the Issues Paper (Earth Tech, 2007a). The Issues Paper is the culmination of literature reviews, anecdotal evidence, background knowledge and site visits by the Expert Panel and should be read in conjunction with this final report.

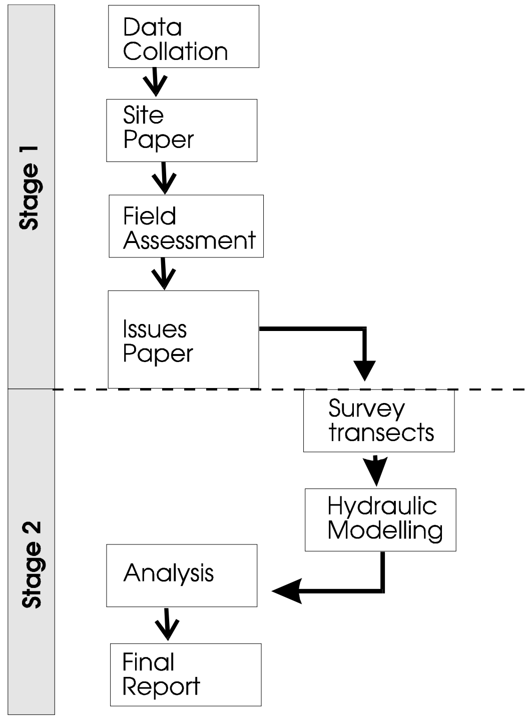


Figure 2 Outline of the steps in the FLOWS method (DNRE, 2002)

This Recommendations Paper identifies the environmental flow requirements for the Kiewa River. For each of the flow requirements identified, the proportion of time the flow event occurs under the current and natural flow regimes is determined, this is referred to as the flow compliance. The change in flow compliance between the natural and current flow regimes gives an indication of the magnitude of anthropogenic impacts on each aspect of the hydrology important to environmental flow requirements. The scope for the report does not include analysis of impacts of the recommended flow regime or details of operational or infrastructure issues in relation to the implementation of environmental water requirements. Recommendations from this report will feed into the Streamflow Management Plan for the Kiewa River.

The format of this report is intended to provide clear linkages between identified river assets and processes, intended river health outcomes (vision and objectives) and flow recommendations to achieve these objectives.

1.1 OUTLINE OF THIS REPORT

This report is divided into four sections, the first giving the environmental flow recommendations whilst the second gives technical information upon which the recommendations were based. Background information can be found in the Issues Paper. The structure of the recommendations report is as outlined below:

Section 1 Introduction

Section 2 Environmental Flow Recommendations

Reach Recommendations – The flow recommendations for each reach of the Kiewa River

Section 3 Supporting Recommendations

Section 4 Flow Recommendation Comparisons

There is an accompanying Hydraulic Modelling Report that contributed to the development of flow recommendations. It documents the following:

- Details of survey information obtained for the purpose of assembling the hydraulic models;
- Modelling approach (eg. Assignment of boundary conditions, floodplain-roughness parameter values);
- Individual model details (eg. Layout, cross section details, model output); and
- Model limitations.

This report seeks to link the vision and objective setting process with the final recommendations as presented in this report. The means in which this link is made is documented in Appendix B through a summary of all hydrologic or hydraulic measures used to develop the recommendations. Discussion notes arising through the recommendations workshops have also been included in this appendix where appropriate.

2. Environmental Flow Recommendations

The flow recommendations for each reach are presented below in a standard format with four individual sections. These are:

- **A Summary of the Reach Condition.** These are a brief summary of the hydrology, physical form, fish, water quality/macroinvertebrates, vegetation and wetland condition in the reach. The vision for the reach is also stated. These are taken from information presented in the Issues Paper;
- **The Environmental Flow Objectives.** For each reach, the objectives of environmental flows are presented;
- **Flow Processes and Components.** For each reach, the objectives are linked to the flow processes and flow components required to meet the objective;
- **Flow Recommendations.** The recommendations are presented in a standard table format as used in the FLOWS method. In this table, the controlling criteria are identified. This criteria are the objectives that produce the greatest flow requirement for each flow component. All other objectives related to the flow component (as listed in the column titled 'Objectives') are also met when the controlling criteria are achieved.

The flow recommendations given in this section of the report are designed to bring about a hydraulic condition (e.g. depth of flow or velocity) often enough (frequency) and for a sufficient length of time (duration) to achieve an environmental objective. This environmental objective may be, for example, to maintain an environmental asset such as the volume and depth of pools in a stream. How strong, or for that matter how tenacious, the link is between the hydraulic condition and the environmental objective is explained in the Issues Paper for the Kiewa River FLOWS study. Hence, the Issues Paper provides some scope to judge whether the flows recommended here are likely to achieve the stated environmental objectives.

Aside from uncertainties in relation to the hydrology provided (SKM, 2007), the science (Issues Paper) and the hydraulic analysis (Hydraulic Report) there are hydraulic criteria which the analysis provided for in FLOWS studies does not accurately address. In the case of low flow recommendations the number of cross-sections provided for (one in each of the pools and one on each riffle) does not provide accurate definition of the geometry of the riffle and hence the flow required to meet the hydraulic criteria for recommendations. Where objectives relate to a certain velocity on the margin of channels (F3a) or a velocity on the bed to disturb bio-films (V5) the one-dimensional nature of the hydraulic models, averaging velocities across the cross-section, does not accurately address these objectives.

The analysis conducted in the FLOWS study is relatively accurate for higher flow events that are aiming to inundate features such as benches and floodplains. However, there remain uncertainties regarding the spatial and temporal validity of flow recommendations. Recommendations are developed on a short reach of river to provide flows for the environment. This short reach of river may not be typical of the entire reach it has been chosen to represent. Recommendations are also developed based on the morphology of the river at the time of the survey. Flow events may change the shape of the river channel in the future, threatening the validity of flow recommendations.

It is noted that the vision, condition and objectives were developed for each reach in the Issues Paper without the current and natural flow regimes for each of the reaches. This decision was made to enable the project to progress to the next stage. Hence the vision, condition and objectives developed in the Issues Paper and used herein do not necessarily reflect the impact of changes to the flow regime on river health. In particular, the compliance calculations (Section 4) indicate that objectives identifying the need to restore an environmental asset may only be achieved through both compliance to flow recommendations and improvements to other aspects of river health.

The 'or natural' clause

The 'or natural' clause on the low flow and high flow recommendations indicate that flow is recommended to be equal to or above the value specified for that season except when flows ***naturally*** fall below that value. For the freshes and larger events, the 'or natural' clause refers to the frequency and duration of the event. That is, the event occurs for the duration and frequency specified unless the particular event would be ***naturally*** less frequent or of a shorter duration.

In practice the 'or natural' clause implies that water may be extracted down to the specified flow magnitude but that the extractions should not cause flows drop below this magnitude. An example of how the 'or natural' clause may be applied to the frequency of events is that you simply allow the recommended number of events to occur in a season and can then extract or store the rest. If the recommended number of events do not occur in that season, and this reduction in frequency was not caused by extraction or storages, then compliance with the flow recommendation has still been achieved. Compliance is achieved under natural variations in hydrology rather than changes imposed by anthropogenic use.

Rates of Rise and Fall

While specific flow recommendations (flow, frequency and durations) are the most critical component of the recommendations, the maximum allowable rates of rise and fall leading up to the particular flow is also important. When managing flow events, the rate of decrease in flow cannot be too great to ensure that aquatic organisms are not stranded on benches or that groundwater retained in river banks as river levels drop does not cause bank collapse. Setting maximum allowable rates of rise and fall at those that occur under natural conditions will increase the frequency of rapid fluctuations in water level. Such an increased frequency of high disturbance events may impact on the ecology of the river channel.

It is recognised that the specification of intra-daily limits on rates of rise and fall may have more relevance to the typical duration of fluctuations in flow from the hydroelectric scheme. However, the hydrology provided to undertake this study (SKM, 2007) is daily flow data. Thus the time step in the hydrology is not of a resolution that is sufficient to examine suitable rates of rise and fall over a number of hours (intra-daily).

The natural flow regime

The natural flow regime is based on the report *Kiewa River Environmental Flows: Update of REALM Model and Derivation of Daily Flows* (SKM, 2007). The natural flow regime refers to the scenario where all direct anthropogenic impacts on streamflows have been removed. That is, the effects of farm dams, private diversions, urban diversions, hydro electricity generation and other impoundments have been removed from the hydrologic model. However, changes in streamflow due to land use changes over time (e.g. land clearing) have not been taken into account.

The current flow regime

The current flow regime refers to the existing level of development in the Kiewa Basin. For the purposes of defining irrigation demands, 2005/06 was the last full irrigation season for which data was available for SKM (2007), and so their calculation of current irrigation was based on this season. This was the final year of tobacco irrigation in the Kiewa and Ovens valleys, so tobacco is assumed to exist in the current scenario used here.

2.1 REACH ONE – UPPER KIEWA RIVER

Reach One includes the section of the Kiewa River from below Mount Beauty Pondage to the confluence with Running Creek (See Map in Appendix A).

Summary of Reach Condition

There is much variability in the valley-setting of the Kiewa River through this reach. The upper and lower ends of the reach are laterally unconfined, floodplain reaches bracketing a reach confined by piedmont deposits and alluvial terraces. Therefore the river transitions between meandering and relatively straight streams with coarse bed load. Several important fish habitats including cascades, runs, riffles and pools exist within this reach. Bank-overhangs and large wood are also present along with high-flow channels and islands. There appears to be the usual range of aquatic insects expected in a foothills river such as this. There was no evidence of any obvious decline in water quality in this reach, which is confirmed by the range of aquatic insects observed. The contemporary condition of the riparian vegetation is generally quite poor, both in extent and in quality. Nonetheless, the overall condition of the reach is good in terms of environmental assets associated with physical form, macroinvertebrates, water quality and fish habitat.

Reach Vision

An ecologically healthy reach where channel morphology provides diverse habitat for flora and fauna within a wide and near continuous fringe of riparian vegetation.

Summary of objectives for Reach One

Physical Form

Maintain riffle substrate

Maintain pool volume

Create bed form, bars, maintain-channel depth

Facilitate bench construction

Continue plan form development, maintain-channel width

Fish

Restore self sustaining populations of Murray Crayfish

Restore self sufficient populations of Two-spined Blackfish

Restore self sufficient populations of Mountain Galaxias in presence of introduced predators

Macroinvertebrates and Water Quality

Maintain communities in riffles

Vegetation

Maintain the presence and diversity of epilithic micro-plants (aquatic bryophytes growing on rocks) in cascades and falls

Table 1 Flow Processes and Components – Reach One

Asset	Environmental Objective	No	Flow Process/Function	Flow component	Timing
Physical form	Maintain riffle substrate	P1	Scour interstitial and surficial sands from riffles	Low flow	Continuous
	Maintain pool volume	P2	Scour fine sediment (sands) from pools	Fresh	Anytime
	Create bed form, bars and maintain channel depth	P3	Overturn gravels and cobbles on bed	Fresh	Anytime
	Facilitate bench construction	P5	Sand, silt and clay deposition along channel margins	Fresh	Winter and Spring
	Continue plan-form development, maintain channel width	P6	Bank erosion and deposition on channel meanders	Bankfull	Anytime
Fish	Restore self sustaining populations of Murray Crayfish	F2a	Restore interstitial spaces between woody debris items and amongst boulder/cobble substrate	(a) Low flow	Continuous
		F2b		(b) High flow fresh and above	Anytime
	Restore self sustaining populations of Two-spined Blackfish	F3a	Ensure depth in slow flowing pools and runs in association with cobble/boulder and LWD and SWD snags and snag-piles.	Low flow	Summer
	Restore self sufficient populations of Mountain Galaxias (*Galaxias olidus* spp.) in presence of introduced predators	F5a	(a) Ensure the presence of shallow complex cobble/boulder habitat, minor anabranch channels, and through-boulder flow.	(a) Low flow	(a) Low flow season
		F5b	(b) Ensure slow stage recession after freshes to limit potential to strand galaxids in such shallow refuge habitat	(b) Low flow fresh	(b) Low flow season
Macroinvertebrates	Maintain communities in riffles	M1	Maintain water depths of at least 10cm over rocks in the upstream cascade	Low flow	All year
Vegetation	Facilitate the return and/or persistence of native riparian vegetation on banks and in the riparian zone by maintaining an appropriate flow regime.	V1d	(d) Ensure the frequency of overbank flows in the high flow season remains close to natural.	(d) Bankfull	(d) July to November

Asset	Environmental Objective	No	Flow Process/Function	Flow component	Timing
	Maintain the presence and a diversity of epilithic micro-plants (bryophytes growing on bryophytes and rocks) in cascades and falls.	V7	Continuously wet or submerge the tops and faces of most rocks in cascades in 90% of years in order to sustain aquatic bryophytes	Low flow	January to June

Table 2 Flow recommendations for Reach One – Upper Kiewa River

Compliance Point– Mongans Bridge					***Gauge Number - 402203***	
Flow					***Rationale***	
Period	***Flow Type***	***Magnitude***	***Frequency***	***Duration***	***Objectives***	***Controlling Criteria***
Dec-May	Low flow	259ML/day (or natural)	continuous	continuous	P1, F2a, **F5a**, M1, V7	Inundate edge habitat
Jul-Nov	High flow fresh	8122ML/day	1/season (or natural)	1 day (or natural)	**V1d**	Achieve overbank flooding
Jan-Dec	Fresh	6480ML/day	1/yr (or natural)	1 day (or natural)	**P5**	Inundate benches to facilitate accretion and evolution of in-stream and floodplain features
Jan-Dec	Fresh	8122ML/day	1/yr (or natural)	1 day (or natural)	**P6**[2]**,** P2, F2b	Maintain the competence of flows to scour bank material and for alluvial landforms to thereby evolve

[2] Some of the environmental objectives such as P6 are met by large flows, generally described as bankfull or overbank events depending on whether they fill the channel or cause flooding. Although these flows are described in the Issues Paper and in the tables of flow processes and components (e.g. Table 1) as bankfull or overbank, where the reach is confined (Reach 1) or incised (Reaches 5 and 6) the recommended flow events have been described as a type of fresh (e.g. Table 2). Describing larger events as bankfull or overbank on Reach 1, 5 or 6 would be misleading as the physical reality of the inundation caused by these events would be altogether different.

Compliance Point– Mongans Bridge					***Gauge Number - 402203***	
Flow					***Rationale***	
Period	***Flow Type***	***Magnitude***	***Frequency***	***Duration***	***Objectives***	***Controlling Criteria***
Jan-Dec	Fresh	30240ML/day	1/20yrs (or natural)	1 day (or natural)	**P3**	Mobilise the gravel bed so pools etc can reform as channel migrates laterally

Notes:

- A three day independence is recommended between events.
- Flow recommendations for each flow component do not have to be discrete. For example an overbank event recommended once every two years will also satisfy the requirement for a bankfull event and one of the high flow freshes.
- The controlling criteria relates to the objective that requires the highest flow to be achieved for the highest frequency and longest duration.
- Meeting the geomorphic objectives of P2, P3, P5 and P6 will be dependent on retaining the flow events specified for each objective and those flow events exceeding it.
- F3a: the low flow meets the F3a objective if it does not exceed the specified volume for more than 14 days.

Table 3 Recommended average and maximum rates of rise and fall (expressed as the change in discharge of the event divided by the length of the event, ML/day/day)

Reach/Site	Period	Flow Component	Rate of Rise (ML/day/day)		Rate of Fall (ML/day/day)	
			AVE rate of rise	**MAX rate of rise**	**AVE rate of fall**	**MAX rate of fall**
1 Upper Kiewa River at Coral Bank	Dec – May	Low flow fresh	632	3847	233	1239
	Jun - Nov	High flow fresh	229	1829	67	509

It is important to note that the flow recommendations for each reach are set based on the environmental objectives for that reach and the hydraulic criteria required to achieve these objectives. Hence, the flows recommended for a reach may result in many of the objectives for downstream reaches being met. For instance, compliance to the above flows recommended for Reach 1 may be influenced by the flows recommended in the upstream reach, Reach 4 Mountain Creek. In turn, the flows from Reach 1, Reach 4 and Reach 5 (Running Creek) may all influence the compliance to the flow recommendation for Reach 2 given below.

2.2 REACH TWO – MIDDLE KIEWA RIVER

Reach Two represents the section of Kiewa River from Running Creek to the confluence with Yackandandah Creek (see map in Appendix A).

Summary of Reach Condition

The degree of valley control in this reach is low, giving rise to unconfined, mixed load, meandering channels set in an overall anabranching pattern. The channel form has been influenced by rock beaching and willows. Invertebrate fauna is diverse and therefore water quality is unlikely to be low. Several important fish habitats including pools, runs and riffles, backwaters and many floodplain wetlands, bank-overhangs and large wood exist within the reach. The overall condition of riparian vegetation is similar to Reach 1. The riparian zone is poor and the major issues are extent and quality. The wetlands are likely to be in a degraded condition due to stock access, lack of a woodland fringe around wetlands and land clearing. However, the overall condition of the reach is good disregarding the condition of the riparian vegetation and wetlands.

Reach Vision

An ecologically healthy reach where channel morphology provides diverse habitat for flora and fauna within a wide and near continuous fringe of riparian vegetation.

Summary of objectives for Reach Two

Physical Form

Maintain riffle substrate

Maintain pool volume

Create bed form, bars, maintain-channel depth

Maintain pool habitat around large wood

Facilitate bench construction

Continue plan-form development, maintain-channel width

Continue accretion of the floodplain

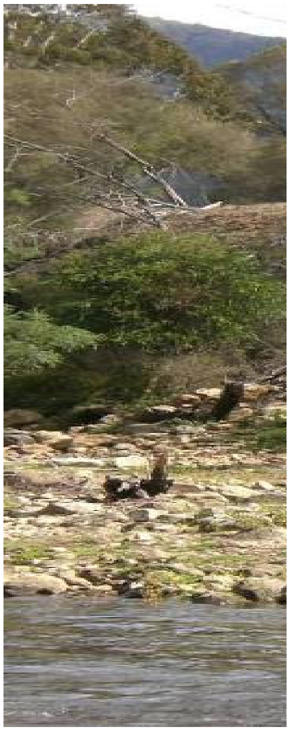
Maintain the anabranching pattern

Fish

Restore self sufficient populations of Murray Cod

Restore self sustaining populations of Murray Crayfish

Restore self sufficient populations of River Blackfish



Restore small bodied native fish populations favouring wetland habitats in wetland or backwater

Macroinvertebrates and Water Quality

Maintain communities in riffles

Maintain communities in snags

Vegetation

Facilitate the return and/or persistence of native riparian vegetation on banks and in the riparian zone

Maintain the ruderal characteristics and low abundance of vegetation colonising gravel and cobble bars

Limit the establishment of terrestrial woody perennials, especially non-native species in the family Salicaceae

Increase the abundance and diversity of in-channel macrophytes

Wetlands

Maintain wetland resilience (capacity to recover) through appropriate water and land management.

Table 4 Flow Processes and Components – Reach Two

Asset	Environmental Objective	No.	Flow Process/Function	Flow component	Timing
Physical form	Maintain riffle substrate	P1	Scour interstitial and surficial sands from riffles	Low flow	Continuous
	Maintain pool volume	P2	Scour fine sediment (sands) from pools	Fresh	Anytime
	Create bed form, bars and maintain channel depth	P3	Overturn gravels and cobbles on bed	Fresh	Anytime
	Maintain pool habitat around large wood	P4	Maintain scour holes around large wood	High flows and above	Anytime
	Facilitate bench construction	P5	Sand, silt and clay deposition along channel margins	Fresh	Winter
	Continue plan-form development, maintain channel width	P6	Bank erosion and deposition on channel meanders	Bankfull	Anytime
	Continue accretion of the floodplain	P7	Deposition of sediments onto the floodplain	High flows and above	Anytime
	Maintain the anabranching channel pattern	P8	Initiate and propagate scour on and through the floodplain	Overbank	Anytime
Fish	Restore self sustaining populations of Murray Cod (a) Provide low flow refuge habitat	F1a	(a) Restore depth in water in pools in association with LWD snags and snag-piles	(a) Low flow	(a) Summer low flow period
	(b) Enable pre-spawning (upstream)	F1b	(b) Provide minimum depth for fish passage	(b) High flow	(b) September-October
	(c) Post-spawning downstream movement	F1c	(c) Provide minimum depth for fish passage	(c) Low flow fresh	(c) November-December
	(d) Promote subsequent larval/juvenile survival through enhanced secondary productivity	F1d	(d) Sweep energy and food resources into the stream	(d) Bankfull	(d) Late winter high flow period
	Restore self sustaining populations of Murray Crayfish	F2a	Restore interstitial spaces between woody debris items and amongst boulder/cobble substrate	(a) Low flow	Continuous
		F2b		(b) High flow fresh and above	Anytime
Fish (cont.)	Restore self sustaining populations of River Blackfish	F3a	Restore depth in slow flowing pools and runs in association with cobble/boulder and LWD and SWD snags and snag-piles.	Low flow	Summer
	Restore populations of small bodied native fish favouring wetland habitats (e.g. *Galaxias rostratus*, *Nannoperca australis*, *Hypseleotris* spp.)	F4a	(a) Restore periodic lateral connectivity with floodplain wetlands	(a) Overbank	(a) Winter-spring high flow period
		F4b	(b) Restore low velocity backwater habitat	(b) Low flow	(b) Late spring-summer low flow period

Asset	Environmental Objective	No.	Flow Process/Function	Flow component	Timing
Macroinvertebrates	Maintain communities in riffles	M1	Maintain water depths of at least 10cm over pebbles and gravel	Low flow	All year
	Maintain communities on snags	M2	Keep snags especially those along the bank partially submerged during the low flow seasons	Low flow	All year
Vegetation	Facilitate the return and/or persistence of native riparian vegetation on banks and in the riparian zone by maintaining an appropriate flow regime.	V1a	(a) Maintain duration of near bankfull flows during cooler months (close to natural) to ensure established trees (currently or in future) have adequate soil moisture	(a) Bankfull	(a) July to September
		V1b	(b) Ensure the duration of low flows in summer-autumn remains similar to natural in most years so that established trees (currently or in future) do not suffer moisture stress during summer	(b) Low flow	(b) January to April
		V1c	(c) Ensure a flood with a spring recession occurs on average once in every five years to provide a regeneration opportunity	(c) Overbank	(c) September to October
		V1d	(d) Ensure the frequency of overbank flows in the high flow season remains close to natural.	(d) Overbank	(d) July to November
	Maintain the ruderal characteristics and low abundance of vegetation colonising gravel and cobble bars	V2a	Inundate bars at least once per growing season for a short period, and once during the cooler months for a much longer period, in order to severely stress existing non-woody species and to prevent woody species establishing and persisting	(a) Low flow fresh	(a) December to April
		V2b		(b) High flow fresh or bankfull or overbank flows	(b) May to September
	Limit the establishment of terrestrial woody perennials, especially non-native species in the family Salicaceae on cobble and gravel bars.	V3	Avoid flood recessions during seed dispersal periods of Black Willow (and for one month after) in order to minimise likelihood of germination and early seeding establishment of willows	Flow recession	November-January
Wetlands	Maintain wetland resilience (capacity to recover) through appropriate water and land management	W1a	Mimic the natural occurrence of overbank flows, particularly in relation to timing and duration so that the flooding of wetlands lasts long enough for wetlands plants to successfully complete reproduction.	(a) Overbank	(a) July-December
		W1b		(b) Drying	(b) July-December

Table 5 Flow recommendations for Reach Two – Middle Kiewa River

Compliance Point – Kiewa River @ Kiewa (Main Stem) and Kiewa River @ Kiewa (Anabranch)					***Gauge Numbers – 402222 and 402220***	
Flow					***Rationale***	
Period	***Flow Type***	***Magnitude***	***Frequency***	***Duration***	***Objectives***	***Controlling Criteria***
Dec-May	Low flow	346ML/day (or natural)	continuous	continuous	P1, F1a, F1c, F2a, **F4b**, M1, M2	Inundate channel margin in areas where low velocity flow dominates (shallow flow, low lateral gradient)
Dec-Apr	Low flow fresh	605ML/day	1/season (or natural)	7 days (or natural)	**V2a**	Inundation required briefly to drown terrestrial species
Jun-Nov	High flow	1184ML/day (or natural)	continuous	continuous	**P4**, **P7,** F1b, V2b	Maintain scour holes under large woody debris and continue floodplain construction through vertical accretion and lateral migration of the channel
Jul-Sep	High flow fresh	3888ML/day	2/season (or natural)	3 days (or natural)	**V1a**	High flows long enough to re-charge soil moisture in root zone of vegetation along top of bank. Retain a proportion of natural seasonal cumulative duration
Jan-Dec	Fresh	1728ML/day	4/yr (or natural)	4 days (or natural)	**P2, F2b,** P3, P5	Achieve a phase shift in the shear stress distribution to export sands from pools
Jul-Sep	Bankfull	6048ML/day	1/season (or natural)	3 days (or natural)	**F1d**	Inundate significant portion of channel with bankfull/ overbank flow

Compliance Point – Kiewa River @ Kiewa (Main Stem) and Kiewa River @ Kiewa (Anabranch)					***Gauge Numbers – 402222 and 402220***	
Flow					***Rationale***	
Period	***Flow Type***	***Magnitude***	***Frequency***	***Duration***	***Objectives***	***Controlling Criteria***
Jan-Dec	Bankfull	6912ML/day	1/yr (or natural)	1 day (or natural)	**P6**	Maintain the competence of flows to scour bank material and for alluvial landforms to thereby evolve
Jun-Nov	Overbank	6912ML/day	1/season (or natural)	2 days (or natural)	**F4a**	Maintain natural periodicity of overbank or 'wetland filling' flows
Sep-Oct	Overbank	6912ML/day	1/ 5yrs (or natural)	3 days (or natural)	**V1c**	Recession to occur in spring
Jul-Dec	Overbank	6912ML/day	1/season (or natural)	2 days (or natural)	**W1a**	Inundate most of wetlands on floodplain, including small and unrecognised ones
Jul-Nov	Overbank	6912ML/day	1/season (or natural)	2 days (or natural)	**V1d**	Achieve overbank flooding
Jan-Dec	Overbank	5616ML/day	2/yr (or natural)	2 days (or natural)	**P8**	Maintain small to moderate floods that initiate and scour channels through the floodplain

Notes:

- The 'or natural' qualification on the low flow recommendation will ensure natural cease to flow frequency and duration in this reach. To meet objective V1b there shall be no increase in the aggregate duration and frequency of cease to flows to ensure that established trees do not suffer moisture stress during summer.
- A three day independence is recommended between events.
- Flow recommendations for each flow component do not have to be discrete. For example an overbank event recommended once every two years will also satisfy the requirement for a bankfull event and one of the high flow freshes.
- The controlling criteria relates to the objective that requires the highest flow to be achieved for the highest frequency and longest duration.
- Meeting the geomorphic objectives of P2 to P8 will be dependent on retaining the flow events specified for each objective and those flow events exceeding it.

- F3a: the low flow meets the F3a objective if it does not exceed the specified volume for more than 14 days
- V3 requires further research in order to specify a flow recommendation, and is therefore omitted from (refer Section 3.2.5).
- Although the objectives W1a and W1b have the same flow magnitude, the flow required to fill the channel, the purpose of the objectives is different. W1a requires overbank flows to inundate wetlands during the wetter months between July and December. However, W1b requires no increase in the frequency and duration of overbank flooding in the dryer months between January and June, that is unseasonal flooding.

Table 6 Recommended average and maximum rates of rise and fall (expressed as the change in discharge of the event divided by the length of the event, ML/day/day)

Reach/Site	Period	Flow Component	Rate of Rise (ML/day/day)		Rate of Fall (ML/day/day)	
			AVE rate of rise	**MAX rate of rise**	**AVE rate of fall**	**MAX rate of fall**
2 Middle Kiewa River at Kiewa	Dec – May	Low flow fresh	501	3872	373	2383
	Jun - Nov	High flow fresh	155	1735	110	806

2.3 REACH THREE – LOWER KIEWA RIVER

Reach Three encompasses the Kiewa River, which extends from Yackandandah Creek to the Murray River.

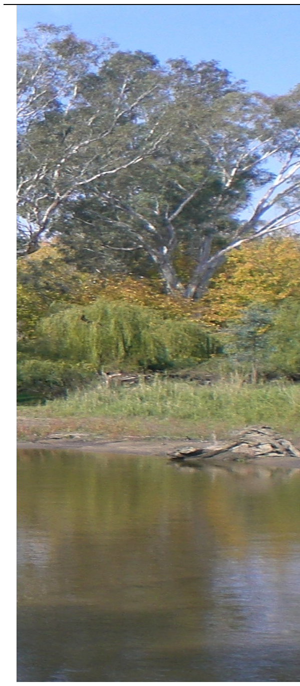
Summary of Reach Condition

This reach is an unconfined, mixed load, meandering stream in an anabranching river pattern. The bed of the Kiewa River has generally aggraded with the pools forming at meander bends and large wood being of reduced volume and surface area. Water quality is unlikely to be low and there appears to be a diversity of lowland invertebrate fauna existing within the reach. Deep pools, runs, riffles, backwaters, wetlands, bank overhangs and large wood are all valuable habitat for fish, which exist throughout the reach. The vegetation extent (width and longitudinal continuity) is more valuable compared to Reaches 1 and 2. However the vegetation quality is still low due to lack of lifeform diversity, weediness and fallen logs, which are both structural characteristics that affect habitat value. It has very low levels of recruitment, for reasons not determined. Stock access has led to modification and degradation of the wetlands. In addition, the floodplain has undergone extensive clearing and the wetlands lack a fringe of trees. The overall condition of the reach is somewhat poorer than Reach 2 due to the sand slug.

Reach Vision

A healthy working reach which displays symptoms of channel form recovery sufficient to sustain fish populations within a near continuous fringe of riparian vegetation.

Summary of objectives for Reach Three



Physical Form

Maintain riffle substrate

Maintain pool volume

Create bed form, bars, maintain-channel depth

Maintain pool habitat around large wood

Facilitate bench construction

Continue plan-form development, maintain-channel width

Continue accretion of the floodplain

Maintain the anabranching pattern

Fish

Restore self sufficient populations of Murray Cod

Restore self sustaining populations of Murray Crayfish

Restore small bodied native fish favouring wetland habitats

Macroinvertebrates and Water Quality

Maintain communities in riffles

Maintain communities in snags

Vegetation

Facilitate the return and/or persistence of native riparian vegetation on banks and in the riparian zone

Maintain the ruderal characteristics and low abundance of vegetation colonising gravel and cobble bars

Limit the establishment of terrestrial woody perennials, especially non-native species in the family Salicaceae

Wetlands

Maintain wetland resilience (capacity to recover) through appropriate water and land management

Table 7 Flow Processes and Components – Reach Three

Asset	Environmental Objective	No.	Flow Process/ Function	Flow component	Timing
Physical Form	Maintain riffle substrate	P1	Scour interstitial and surficial sands from riffles	Low flow	Continuous
	Maintain pool volume	P2	Scour fine sediment (sands) from pools	Fresh	Anytime
	Create bed form, bars and maintain channel depth	P3	Overturn gravels and cobbles on bed	Fresh	Anytime
	Maintain pool habitat around large wood	P4	Maintain scour holes around large wood	High flows and above	Anytime
	Facilitate bench construction	P5	Sand, silt and clay deposition along channel margins	Fresh	Winter
	Continue plan-form development, maintain channel width	P6	Bank erosion and deposition on channel meanders	Bankfull	Anytime
	Continue accretion of the floodplain	P7	Deposition of sediments onto the floodplain	High flows and above	Anytime
	Maintain the anabranching channel pattern	P8	Initiate and propagate scour on and through the floodplain	Overbank	Anytime
Fish	Restore self sustaining populations of Murray Cod (a) Provide low flow refuge habitat	F1a	(a) Restore depth in water in pools in association with LWD snags and snag-piles	(a) Low flow	(a) Summer low flow period
	(b) Enable pre-spawning (upstream)	F1b	(b) Provide minimum depth for fish passage	(b) High flow	(b) September-October
	(c) Post-spawning downstream movement	F1c	(c) Provide minimum depth for fish passage	(c) Low flow fresh	(c) November-December
	(d) Promote subsequent larval/juvenile survival through enhanced secondary productivity	F1d	(d) Sweep energy and food resources into the stream	(d) Bankfull	(d) Late winter high flow period
	Restore self sustaining populations of Murray Crayfish	F2a	Restore interstitial spaces between woody debris items and amongst boulder/cobble substrate	(a) Low flow	Continuous
		F2b		(b) High flow fresh and above	Anytime
	Restore populations of small bodied native fish	F4a	(a) Ensure periodic lateral connectivity with floodplain wetlands	(a) Overbank	(a) Winter-spring high flow period

Asset	Environmental Objective	No.	Flow Process/ Function	Flow component	Timing
	favouring wetland habitats (e.g. *Galaxias rostratus, Nannoperca australis, Hypseleotris* spp.)	F4b	(b) Ensure low velocity backwater habitat	(b) Low flow	(b) Late spring-summer low flow period
Macro invertebrates	Maintain communities in riffles	M1	maintain water depths of at least 10cm over sand and pebbles	Low flow	All year
	Maintain communities on snags	M2	Keep snags especially those along the bank partially submerged during the low flow seasons	Low flow	All year
Vegetation	Facilitate the return and/or persistence of native riparian vegetation on banks and in the riparian zone by maintaining an appropriate flow regime.	V1a	(a) Maintain duration of near bankfull flows during cooler months (close to natural) to ensure established trees (currently or in future) have adequate soil moisture.	(a) High flow fresh	(a) July to September
		V1b	(b) Ensure the duration of low flows in summer-autumn remains similar to natural in most years so that established trees (currently or in future) do not suffer moisture stress during summer.	(b) Low flow	(b) January to April
		V1c	(c) Ensure a flood with a spring recession occurs on average once in every five years to provide a regeneration opportunity.	(c) Recession of overbank flow	(c) September to October
		V1d	(d) Ensure the frequency of overbank flows in the high flow season remains close to natural.	(d) Overbank	(d) July to November
	Maintain the ruderal	V2a	Inundate bars at least once per	(a) Low flow fresh	(a) December to April

Asset	Environmental Objective	No.	Flow Process/ Function	Flow component	Timing
	characteristics and low abundance of vegetation colonising gravel and cobble bars	V2b	growing season for a short period, and once during the cooler months for a much longer period, in order to severely stress existing non-woody species and to prevent woody species establishing and persisting.	(b) High flow fresh or bankfull or overbank flows	(b) May to September
	Limit the establishment of terrestrial woody perennials, especially non-native species in the family Salicaceae on cobble and gravel bars.	V3	Avoid flood recessions during seed dispersal periods of Black Willow (and for one month after) in order to minimise likelihood of germination and early seeding establishment of willows.	Flow recession	November-January
Wetlands	Maintain wetland resilience (capacity to recover) through appropriate water and land management	W1a	Mimic the natural occurrence of overbank flows, particularly in relation to timing and duration so that the flooding of wetlands lasts long enough for wetlands plants to successfully complete reproduction.	(a) Overbank	(a) July-December
		W1b		(b) Drying	(b) July-December

Table 8 Flow recommendations for Reach Three – Lower Kiewa River

Compliance Point – Kiewa River @ Bandiana					***Gauge Number - 402205***	
Flow					***Rationale***	
Period	***Flow Type***	***Magnitude***	***Frequency***	***Duration***	***Objectives***	***Controlling Criteria***
Dec-May	Low flow	432ML/day (or natural)	continuous	continuous	P1, F1a, F1c, F2a, **F4b**, M1, M2,V2a	Inundate channel margin areas where low velocity flow dominates (shallow flow, low lateral gradient)

Compliance Point – Kiewa River @ Bandiana					***Gauge Number - 402205***	
Flow					***Rationale***	
Period	***Flow Type***	***Magnitude***	***Frequency***	***Duration***	***Objectives***	***Controlling Criteria***
Jun-Nov	High flow	1287ML/day (or natural)	continuous	continuous	**P4, P7,** F1b,V2b	Maintain scour holes under large woody debris and continue floodplain construction through vertical accretion and lateral migration of the channel
Jul-Sep	High flow fresh	2592ML/day	2/season (or natural)	3 days (or natural)	**V1a**	High flows long enough to re-charge soil moisture in root zone of vegetation along top of bank. Retain a proportion of natural seasonal cumulative duration
Jul-Sep	Bankfull	4320ML/day	1/season (or natural)	6 days (or natural)	**F1d**	Inundate significant portion of channel with bankfull/ overbank flow
Jan-Dec	Bankfull	3024ML/day	4/yr (or natural)	4 days (or natural)	**P6,** P3, P5, V1d	Maintain the competence of flows to scour bank material and for alluvial landforms to thereby evolve
Sept-Oct	Overbank	5184ML/day	1/5yrs (or natural)	7 days (or natural)	**V1c**	Recession to occur in spring
Jun-Nov	Overbank	5184ML/day	2/season (or natural)	4 days (or natural)	**F4a**	Maintain natural periodicity of overbank or 'wetland filling' flows

Compliance Point – Kiewa River @ Bandiana					***Gauge Number - 402205***	
Flow					***Rationale***	
Period	***Flow Type***	***Magnitude***	***Frequency***	***Duration***	***Objectives***	***Controlling Criteria***
Jul-Dec	Overbank	5184ML/day	1/season (or natural)	4 days (or natural)	**W1a**	Inundate most of wetlands on floodplain, including small and unrecognised ones
Jan-Dec	Overbank	4628ML/day	2/yr (or natural)	4 days (or natural)	**P2, F2b,** P8	Achieve a phase shift in the shear stress distribution to export sands from pools

Notes:

- The ‘or natural’ qualification on the low flow recommendation will ensure natural cease to flow frequency and duration in this reach. To meet objective V1b there shall be no increase in the aggregate duration and frequency of cease to flows to ensure that established trees do not suffer moisture stress during summer.
- A three day independence is recommended between events.
- Flow recommendations for each flow component do not have to be discrete. For example an overbank event recommended once every two years will also satisfy the requirement for a bankfull event and one of the high flow freshes.
- The controlling criteria relates to the objective that requires the highest flow to be achieved for the highest frequency and longest duration.
- F3a: the low flow meets the F3a objective if it does not exceed the specified volume for more than 14 days.
- V3 requires further research in order to specify a flow recommendation, and is therefore omitted from Table 8 (refer Section3.2.5).
- Meeting the geomorphic objectives of P2 to P8 will be dependent on retaining the flow events specified for each objective and those flow events exceeding it.
- Although the objectives W1a and W1b have the same flow magnitude, the flow required to fill the channel, the purpose of the objectives is different. W1a requires overbank flows to inundate wetlands during the wetter months between July and December. However, W1b requires no increase in the frequency and duration of overbank flooding in the dryer months between January and June, that is unseasonal flooding.

Table 9 Recommended average and maximum rates of rise and fall (expressed as the change in discharge of the event divided by the length of the event, ML/day/day)

Reach/Site	Period	Flow Component	Rate of Rise (ML/day/day)		Rate of Fall (ML/day/day)	
			AVE rate of rise	**MAX rate of rise**	**AVE rate of fall**	**MAX rate of fall**
Lower Kiewa River at Murray Valley Highway	Dec – May	Low flow fresh	615	4775	373	2383
	Jun - Nov	High flow fresh	171	1754	110	806

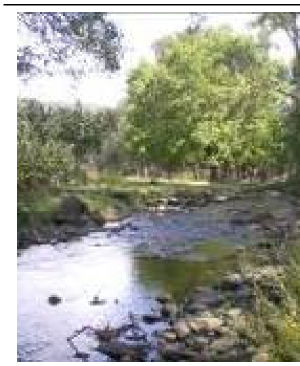
2.4 REACH FOUR – MOUNTAIN CREEK

Reach Four encompasses Mountain Creek, which is a major tributary of Kiewa River.

Summary of Reach Condition

Mountain Creek is an unconfined, low sinuosity stream close to the Kiewa River with confinement progressively increasing upstream as the valley narrows. Although of low sinuosity, the stream is laterally active and benches do form at sites where the channel migrates. A diverse assemblage of invertebrates is present indicating no water quality problems within the reach. There is upland stream habitat for most of the reach for fish consisting of cobble and boulder strewn cascades, pools, runs and riffles. The condition of riparian vegetation varies from medium for downstream parts closest to the confluence with the Kiewa River to good further upstream. Clearing has fragmented the riparian fringe of EVC 18 Riparian Forest so that it is no longer continuous. The overall condition of the reach is good in terms of physical form, water quality and the riparian zone.

Reach Vision



An ecologically healthy reach with a diverse bed form that provides a variety of habitats for flora and fauna within increasingly native riparian vegetation.

Summary of objectives for Reach Four

Physical Form

Maintain riffle substrate

Maintain pool volume

Create bed form, bars, maintain-channel depth

Facilitate bench construction

Continue plan-form development, maintain-channel width

Continue accretion of the floodplain

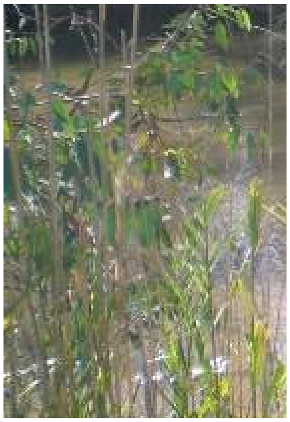
Fish

Restore self sustaining populations of Murray Crayfish

Restore self sufficient populations of Two-spined Blackfish

Enhance egg and larval survival in Two-spined Blackfish

Restore self sufficient populations of Mountain Galaxias in presence of introduced predators



Macroinvertebrates and Water Quality

Maintain communities in riffles

Vegetation

Facilitate the return and/or persistence of native riparian vegetation on banks and in the riparian zone

Maintain in-channel bio-films at low levels of abundance and with diverse composition

Table 10 Flow Processes and Components – Reach Four

Asset	Environmental Objective	No.	Flow Process/ Function	Flow component	Timing
Physical Form	Maintain riffle substrate	P1	Scour interstitial and surficial sands from riffles	Low flow	Continuous
	Maintain pool volume	P2	Scour fine sediment (sands) from pools	Fresh	Anytime
	Create bed form, bars and maintain channel depth	P3	Overturn gravels and cobbles on bed	Fresh	Anytime
	Facilitate bench construction	P5	Sand, silt and clay deposition along channel margins	Fresh	Winter
	Continue plan-form development, maintain channel width	P6	Bank erosion and deposition on channel meanders	Bankfull	Anytime
	Continue accretion of the floodplain	P7	Deposition of sediments onto the floodplain	High flows and above	Anytime
Fish	Restore self sustaining populations of Murray Crayfish	F2a	Restore interstitial spaces between woody debris items and amongst boulder/cobble substrate	(a) Low flow	Continuous
		F2b		(b) High flow fresh and above	Anytime
	Restore self sustaining populations of Blackfish (e.g. River Blackfish, Two-spined Blackfish)	F3a	(a) Ensure depth in slow flowing pools and runs in association with cobble/boulder and LWD and SWD snags and snag-piles.	(a) Low flow	(a) Summer
		F3b	(b) Avoid artificially high rates of stage recession after high flows to limit stranding of eggs and larvae at spawning sites	(b) High flow fresh	(b) Spring/ early summer
	Restore self sufficient populations of Mountain Galaxias (*Galaxias olidus* spp.) in presence of introduced predators	F5a	(a) Ensure the presence of shallow complex cobble/boulder habitat, minor anabranch channels, and through-boulder flow.	(a) Low flow	(a) Low flow season
		F5b	(b) Ensure slow stage recession after freshes to limit potential to strand galaxids in such shallow	(b) Low flow fresh	(b) Low flow season

Asset	Environmental Objective	No.	Flow Process/ Function	Flow component	Timing
			refuge habitat		
	Enhance egg and larval survival of Two-spined Blackfish	F6	Ensure that small woody debris piles (SWD) can be inundated in the spring and early summer as spawning habitat	High flow/low flow interphase	Spring
Macroinvertebrates	Maintain communities in riffles	M1	Maintain water depths of at least 10cm over the cobbles and boulders	Low flow	All year
Vegetation	Facilitate the return and/or persistence of native riparian vegetation on banks and in the riparian zone by maintaining an appropriate flow regime.	V1d	(d) Ensure the frequency of overbank flows in the high flow season remains close to natural.	(d) Overbank	(d) July to November
	Maintain in-channel bio-films at low levels of abundance and with diverse composition.	V5	Ensure two to three freshes per season to avoid sustained low flow periods, providing average cross-sectional velocities greater than 0.3m s^{-1} for at least one day in order to disturb biofilms and remove some or most of their biomass	Low flow fresh	December-April

Table 11 Flow recommendations for Reach Four – Mountain Creek

Compliance Point – Mountain Creek @ Coopers					***Gauge Number - 402207***	
Flow					***Rationale***	
Period	***Flow Type***	***Magnitude***	***Frequency***	***Duration***	***Objectives***	***Controlling Criteria***
Dec-May	Low flow	17ML/day (or natural)	continuous	continuous	P1, F2a, **F5a**, M1	Inundate edge habitat
Dec-Apr	Low flow fresh	130ML/day	1/season (or natural)	1 day (or natural)	**V5**	Velocity high enough to disturb bio-films at all sections
Jun-Nov	High flow	58ML/day	continuous	continuous	**P7**, F6	Continue floodplain construction through vertical accretion and lateral migration of the channel

Compliance Point – Mountain Creek @ Coopers					***Gauge Number - 402207***	
Flow					***Rationale***	
Period	***Flow Type***	***Magnitude***	***Frequency***	***Duration***	***Objectives***	***Controlling Criteria***
Jan-Dec	Fresh	147ML/day (or natural)	3/yr	3 days	**P2, F2b,** P5	Achieve a phase shift in the shear stress distribution to export sands from pools
Jan-Dec	Bankfull	173ML/day (or natural)	2/yr	2 days	**P6**	Maintain the competence of flows to scour bank material and for alluvial landforms to thereby evolve
Jul-Nov	Overbank	173ML/day	3/season (or natural)	2 days (or natural)	**V1d**	Achieve overbank flooding
Jan-Dec	Overbank	346ML/day (or natural)	1/yr	1 day	**P3**	Mobilise the gravel bed so pools etc can reform as channel migrates laterally

Notes:

- A three day independence is recommended between events.
- Flow recommendations for each flow component do not have to be discrete. For example an overbank event recommended once every two years will also satisfy the requirement for a bankfull event and one of the high flow freshes.
- The controlling criteria relates to the objective that requires the highest flow to be achieved for the highest frequency and longest duration.
- Meeting the geomorphic objectives of P2, P3 and P5 to P7 will be dependent on retaining the flow events specified for each objective and those flow events exceeding it.
- F3a: the low flow meets the F3a objective if it does not exceed the specified volume for more than 14 days.

- There is a low compliance on the V5 recommendation for this reach. This recommendation aims to achieve a velocity of 0.3 m/s to disturb biofilms. It is considered that this compliance is low because the hydraulic modelling used is one-dimensional, averaging velocities across the cross-sectional area. More complex hydraulic modelling or field measurements are likely to reveal that the required velocities are achieved at lower flows and hence compliance is higher. This recommendation has been retained as it is important to achieve the stated objective, the method of determining the whether the hydraulic criteria is met simply needs to be more accurate.

Table 12 Recommended average and maximum rates of rise and fall (expressed as the change in discharge of the event divided by the length of the event, ML/day/day)

			Rate of Rise (ML/day/day)		Rate of Fall (ML/day/day)	
Reach/Site	**Period**	**Flow Component**	**AVE rate of rise**	**MAX rate of rise**	**AVE rate of fall**	**MAX rate of fall**
4 Mountain Creek at Ryder's Property	Dec – May	Low flow fresh	26	147	10	46
	Jun - Nov	High flow fresh	12	85	3	22

2.5 REACH FIVE– RUNNING CREEK

Reach Five encompasses Running Creek, which is a major tributary of Kiewa River.

Summary of Reach Condition

The lower reaches of Running Creek are partly confined, primarily by the valley margin and associated colluvial fans. Running Creek is a low sinuosity stream with narrow floodplain pockets. The system is probably still going through a phase of adjustment following straightening and deepening. There appears to be a great diversity of aquatic insects within this reach. Apart from the silt on the creek bed other indications of low water quality were not evident. Fish habitat in the lower portion of the reach is in poor condition due to modification by agricultural activity. Fish habitat is severely compromised through largely unrestricted cattle access to the stream.. The condition of riparian vegetation is poor at the downstream end of Running Creek due to land use occurring since European settlement. The overall condition of the reach is poor, particularly in terms of riparian vegetation and fish habitat.

Reach Vision

A healthy working reach which displays symptoms of channel recovery such as a greater diversity in bed form that provides a variety of habitat for flora and fauna within a riparian zone of tree, shrub and ground cover dominated by native species.

Summary of objectives for Reach Five

Physical Form

Maintain riffle substrate

Maintain pool volume

Create bed form, bars, maintain-channel depth

Maintain pool habitat around large wood

Facilitate bench construction

Continue plan-form development, maintain-channel width

Continue accretion of the floodplain

Fish

Restore self sustaining populations of Murray Crayfish

Restore self sufficient populations of Two-spined Blackfish

Enhance egg and larval survival in Two-spined Blackfish

Macroinvertebrates and Water Quality

Maintain communities in riffles

Maintain communities in pools

Vegetation

Facilitate the return and/or persistence of native riparian vegetation on banks and in the riparian zone

Maintain the ruderal characteristics and low abundance of vegetation colonising gravel and cobble bars

Limit the establishment of terrestrial woody perennials, especially non-native species in the family Salicaceae

Minimise opportunities for perennial species such as rhizomatous emergent macrophytes or grasses to encroach into the channel

Table 13 Flow Processes and Components – Reach Five

Asset	Environmental Objective	No.	Flow Process/ Function	Flow component	Timing
Physical Form	Maintain riffle substrate	P1	Scour interstitial and surficial sands from riffles	Low flow	Continuous
	Maintain pool volume	P2	Scour fine sediment (sands) from pools	Fresh	Anytime
	Create bed form, bars and maintain channel depth	P3	Overturn gravels and cobbles on bed	Fresh	Anytime
	Maintain pool habitat around large wood	P4	Maintain scour holes around large wood	High flows and above	Anytime
	Facilitate bench construction	P5	Sand, silt and clay deposition along channel margins	Fresh	Winter
	Continue plan-form development, maintain channel width	P6	Bank erosion and deposition on channel meanders	Fresh	Anytime
	Continue accretion of the floodplain	P7	Deposition of sediments onto the floodplain	High flows and above	Anytime
Fish	Restore self sustaining populations of Murray Crayfish	F2a	Restore interstitial spaces between woody debris items and amongst boulder/cobble substrate	(a) Low flow	Continuous
		F2b		(b) High flow fresh and above	Anytime
	Restore self sustaining populations of Blackfish (e.g. River Blackfish, Two-spined Blackfish)	F3a	(a) Restore depth in slow flowing pools and runs in association with cobble/boulder and LWD and SWD snags and snag-piles.	(a) Low flow	(a) Summer
		F3b	(b) Avoid artificially high rates of stage recession after high flows to limit stranding of eggs and larvae at spawning sites	(b) High flow fresh	(b) Spring/early summer
	Enhance egg and larval survival of Two-spined Blackfish	F6	Ensure that small woody debris piles (SWD) can be inundated in the spring and early summer as spawning habitat	High flow/low flow interphase	Spring
Macroinvertebrates	Maintain communities in riffles	M1	Maintain water depths of at least 10cm over the whole reach	Low flow	All year
	Maintain communities in pools	M3	Flushing flows to remove accumulations of silt	(a) Low flow freshes (b) High flow freshes	a) December-April (low flow fresh period) (b) June-November (high flow fresh period)
Vegetation	Facilitate the return and/or persistence of native riparian vegetation on banks and in the riparian zone by maintaining an appropriate flow regime	V1a	(a) Maintain duration of near bankfull flows during cooler months (close to natural) to ensure established trees (currently or in future) have adequate soil moisture	(a) Bankfull	(a) July to September
		V1b	(b) Ensure the duration of low flows in summer-autumn remains similar to natural in most years so that established trees (currently	(b) Low flow	(b) January to April

Asset	Environmental Objective	No.	Flow Process/ Function	Flow component	Timing
			or in future) do not suffer moisture stress during summer		
		V1c	(c) Ensure a flood with a spring recession occurs on average once in every five years to provide a regeneration opportunity	(c) Recession of overbank flow	(c) September to October
		V1d	(d) Ensure the frequency of overbank flows in the high flow season remains close to natural.	(d) Overbank/ bankfull	(d) July to November
	Maintain the ruderal characteristics and low abundance of vegetation colonising gravel and cobble bars	V2a	Inundate bars at least once per growing season for a short period, and once during the cooler months for a much longer period, in order to severely stress existing non-woody species and to prevent woody species establishing and persisting	(a) Low flow fresh	(a) December to April
		V2b		(b) High flow fresh or bankfull or overbank flows	(b) May to September
	Limit the establishment of terrestrial woody perennials, especially non-native species in the family Salicaceae on cobble and gravel bars.	V3	Avoid flood recessions during seed dispersal periods of Black Willow (and for one month after) in order to minimise likelihood of germination and early seeding establishment of willows	Flow recession	November-January
	Minimise opportunities for perennial species such as rhizomatous emergent macrophytes or grasses to encroach into the channel	V4	Maintain low flows at a velocity likely to deter vegetation encroachment into the stream channel	Low flow	February-April
	Maintain in-channel bio-films at low levels of abundance and with diverse composition.	V5	Ensure two to three freshes per season to avoid sustained low flow periods, providing average cross-sectional velocities greater than 0.3m s^{-1} for at least one day in order to disturb biofilms and remove some or most of their biomass	Low flow fresh	December-April

Table 14 Flow recommendations for Reach Five – Running Creek

Compliance Point – Running Creek @ Running Creek					***Gauge Number - 402206***	
Flow					***Rationale***	
Period	**Flow Type**	**Magnitude**	**Frequency**	**Duration**	**Objectives**	**Controlling Criteria**
Dec-May	Low flow	26ML/day (or natural)	continuous	continuous	P1, F2a, **M1**, M3a	Wet riffles to a minimum depth of 0.1 m
Dec-Apr	Low flow fresh	130ML/day	1/season (or natural)	1 days (or natural)	**V5**	Velocity high enough to disturb bio-films at all sections
Jun-Nov	High flow	47ML/day (or natural)	continuous	continuous	**P4, P7**	Maintain scour holes under large woody debris and continue floodplain construction through vertical accretion and lateral migration of the channel
Jul-Nov	High flow fresh	467ML/day	1/season (or natural)	2 days (or natural)	**V1d**	Achieve overbank flooding
Jul-Sep	High flow fresh	518ML/day	1/2yrs (or natural)	4 days (or natural)	**V1a**	High flows long enough to re-charge soil moisture in root zone of vegetation along top of bank. Retain a proportion of natural seasonal cumulative duration
Jun-Nov	High flow fresh	1123ML/day	1/3yrs (or natural)	2 days (or natural)	**M3b**	Achieve a phase shift in the shear stress distribution to export sands from pools
Sep-Oct	High flow fresh	467ML/day	1/5yrs(or natural)	2 days (or natural)	**V1c**	Recession to occur in spring
Jan-Dec	Fresh	346ML/day	1/yr (or natural)	3 days (or natural)	**P3**	Mobilise the gravel bed so pools etc can reform as channel migrates laterally

Compliance Point – Running Creek @ Running Creek					***Gauge Number - 402206***	
Flow					***Rationale***	
Period	**Flow Type**	**Magnitude**	**Frequency**	**Duration**	**Objectives**	**Controlling Criteria**
Jan-Dec	Fresh	518ML/day	1/yr (or natural)	1 day (or natural)	**P5,** P6	Inundate benches to facilitate accretion and evolution of in-stream and floodplain features
Jan-Dec	Fresh	1123ML/day	1/3yrs (or natural)	1 day (or natural)	**P2, F2b**	Achieve a phase shift in the shear stress distribution to export sands from pools

Notes:

- The 'or natural' qualification on the low flow recommendation will ensure natural cease to flow frequency and duration in this reach. To meet objective V1b there shall be no increase in the aggregate duration and frequency of cease to flows to ensure that established trees do not suffer moisture stress during summer.
- A three day independence is recommended between events.
- Flow recommendations for each flow component do not have to be discrete. For example an overbank event recommended once every two years will also satisfy the requirement for a bankfull event and one of the high flow freshes.
- The controlling criteria relates to the objective that requires the highest flow to be achieved for the highest frequency and longest duration.
- Meeting the geomorphic objectives of P2 to P7 will be dependent on retaining the flow events specified for each objective and those flow events exceeding it.
- Running Creek is incised and, as a result, regular flood events do not inundate the floodplain. Where bankfull events have been prescribed on Running Creek the 1 year ARI has been used as an estimation of the discharge which previously reached the top of bank. Other studies have found the 1 year ARI event to be a reasonable approximation of the bankfull discharge (Leopold et al., 1964). Less frequent, higher discharge events are labelled as freshes and we have used other methods such as shear stress to calculate the discharge required to achieve the stated environmental objective.
- F3a: the low flow meets the F3a objective if it does not exceed the specified volume for more than 14 days.
- There is a low compliance on the F6 recommendation for this reach. The inundation of the small woody debris piles noted on Running Creek is achieved at the frequency required but not for sufficient duration to enhance the egg and larval survival of blackfish. Hence, the F6 recommendation has

not been retained for this reach as the hydraulic analysis undertaken on this objective suggests that the small woody debris piles noted in the field are not important to the spawning of blackfish on Running Creek.

- There is a low compliance on the V2a and V2b recommendations for this reach (refer Appendix B for the flows derived). In both the low flow and high flow seasons there is rarely if ever extended periods with the 0.5-metre depth required to stress or drown terrestrial woody species establishing on bars. Hence, the V2a and V2b recommendations have not been retained for this reach as the hydraulic analysis undertaken on these objectives has demonstrated that these processes are not important on Running Creek. This indicates that over time Running Creek will be susceptible to the establishment of woody species on bars and potentially associated contraction of the channel.
- V3 requires further research in order to specify a flow recommendation, and is therefore omitted from (refer Section 3.2.5).
- The V4 objective for this reach has not been included as a flow recommendation as the hydraulic criterion that achieves this objective is not well understood. A shear stress criterion trialled during the hydraulic investigations yielded unrealistic flow recommendations (refer Appendix B).
- There is a low compliance on the V5 recommendation for this reach. This recommendation aims to achieve a velocity of 0.3 m/s to disturb biofilms. It is considered that this compliance is low because the hydraulic modelling used is one-dimensional, averaging velocities across the cross-sectional area. More complex hydraulic modelling or field measurements are likely to reveal that the required velocities are achieved at lower flows and hence compliance is higher. This recommendation has been retained as it is important to achieve the stated objective, the method of determining the whether the hydraulic criteria is met simply needs to be more accurate.

Table 15 Recommended average and maximum rates of rise and fall (expressed as the change in discharge of the event divided by the length of the event, ML/day/day)

Reach/Site	Period	Flow Component	Rate of Rise (ML/day/day)		Rate of Fall (ML/day/day)	
			AVE rate of rise	MAX rate of rise	AVE rate of fall	MAX rate of fall
5 Running Creek at Connor's Property	Dec – May	Low flow fresh	38	286	15	89
	Jun - Nov	High flow fresh	7	80	3	25

2.6 REACH SIX– YACKANDANDAH CREEK

Reach Six encompasses Yackandandah Creek, which is a major tributary of Kiewa River.

Summary of Reach Condition

Yackandandah Creek has been greatly altered by gold mining operations. Since the cessation of mining, Yackandandah Creek has incised and is now a stream partly confined by alluvial terraces. The planform of Yackandandah Creek is relatively straight, largely due to the incision and current confinement of the creek. Five families of invertebrates were observed but a greater diversity has been recorded at various points throughout the reach. A layer of organic and sedimentary material is present on rocks over most of the stream bed. Other signs of poor water quality are not evident. Fish habitat is very poor because the reach is affected by sedimentation triggered by historical mining. The condition of riparian vegetation in the lower 22 km of Yackandandah Creek is very poor in terms of vegetation extent (longitudinal continuity) and structural characteristics. The overall condition of the reach is poor, mainly due to disturbance by historical gold mining.

Reach Vision

A healthy working reach which displays symptoms of channel recovery sufficient to sustain flora and fauna communities within a corridor of predominantly native vegetation.

Summary of objectives for Reach Six

Physical Form

Maintain riffle substrate

Maintain pool volume

Create bed form, bars, maintain-channel depth

Maintain pool habitat around large wood

Facilitate bench construction

Continue plan-form development, maintain-channel width

Continue accretion of the floodplain

Fish

Restore small bodied native fish favouring wetland habitats or backwaters

Macroinvertebrates and Water Quality

Maintain communities in riffles

Maintain communities in pools

Vegetation

Facilitate the return and/or persistence of native riparian vegetation on banks and in the riparian zone

Maintain the ruderal characteristics and low abundance of vegetation colonising gravel and cobble bars

Limit the establishment of terrestrial woody perennials, especially non-native species in the family Salicaceae

Minimise opportunities for perennial species such as rhizomatous emergent macrophytes or grasses to encroach into the channel

Table 16 Flow Processes and Components – Reach Six

Asset	Environmental Objective	No.	Flow Process/Function	Flow component	Timing
Physical Form	Maintain riffle substrate	P1	Scour interstitial and surficial sands from riffles	Low flow	Continuous
	Maintain pool volume	P2	Scour fine sediment (sands) from pools	Fresh	Anytime
	Create bed form, bars and maintain channel depth	P3	Overturn gravels and cobbles on bed	Fresh	Anytime
	Maintain pool habitat around large wood	P4	Maintain scour holes around large wood	High flows and above	Anytime
	Facilitate bench construction	P5	Sand, silt and clay deposition along channel margins	Fresh	Winter
	Continue plan-form development, maintain channel width	P6	Bank erosion and deposition on channel meanders	Fresh	Anytime
	Continue accretion of the floodplain	P7	Deposition of sediments onto the floodplain	High flows and above	Anytime
Fish	Restore populations of small bodied native fish favouring wetland habitats (e.g. *Galaxias rostratus, Nannoperca australis, Hypseleotris* spp.)	F4a	(a) Restore periodic lateral connectivity with floodplain wetlands	(a) Bankfull and overbank flows	(a) Winter-spring high flow period
		F4b	(b) Restore low velocity backwater habitat	(b) Low flow	(b) Late spring-summer low flow period
Macroinvertebrates	Maintain communities in riffles	M1	Habitat maintenance	Low flow	All year
	Maintain communities in pools	M3	Flushing flows are necessary in both the high and low flow seasons to remove accumulations of silt	(a) Low flow freshes	a) December-April (low flow period)
				(b) High flow freshes	(b) June-November (high flow period)
Vegetation	Facilitate the return and/or persistence of native riparian vegetation on banks and in the riparian zone by maintaining an appropriate flow regime.	V1a	(a) Maintain duration of near bankfull flows during cooler months (close to natural) to ensure established trees (currently or in future) have adequate soil moisture	(a) Bankfull	(a) July to September
		V1b	(b) Ensure the duration of low flows in summer-autumn remains similar to natural in most years so that established trees (currently or in future) do not suffer moisture stress during summer	(b) Low flow	(b) January to April
		V1c	(c) Ensure a flood with a spring recession occurs on average once in every five years to provide a regeneration opportunity	(c) Recession of overbank flow	(c) September to October
		V1d	(d) Ensure the frequency of overbank flows in the	(d) Overbank/ bankfull	(d) July to November

Asset	Environmental Objective	No.	Flow Process/Function	Flow component	Timing
			high flow season remains close to natural.		
Vegetation (cont)	Maintain the ruderal characteristics and low abundance of vegetation colonising gravel and cobble bars	V2a	Inundate bars at least once per growing season for a short period, and once during the cooler months for a much longer period, in order to severely stress existing non-woody species and to prevent woody species establishing and persisting	(a) Low flow fresh	(a) December to April
		V2b		(b) High flow fresh or bankfull or overbank flows	(b) May to September
	Limit the establishment of terrestrial woody perennials, especially non-native species in the family Salicaceae on cobble and gravel bars.	V3	Avoid flood recessions during seed dispersal periods of Black Willow (and for one month after) in order to minimise likelihood of germination and early seeding establishment of willows	Flow recession	November-January
	Minimise opportunities for perennial species such as rhizomatous emergent macrophytes or grasses to encroach into the channel	V4	Maintain low flows at a velocity likely to deter vegetation encroachment into the stream channel	Low flow	February-April

Table 17 Flow recommendations for Reach Six – Yackandandah Creek

Compliance Point – Yackandandah Creek @ Osbornes Flat					***Gauge Number - 402204***	
Flow					***Rationale***	
Period	***Flow Type***	***Magnitude***	***Frequency***	***Duration***	***Objectives***	***Controlling Criteria***
Dec-May	Low flow	16ML/day (or natural)	continuous	continuous	F4b, M1, **M3a, P1**	Maintain low flows over riffles to scour out fine sediments, primarily sands and achieve a phase shift in the shear stress distribution to export sands from pools
Jun-Nov	High flow	65ML/day (or natural)	continuous	continuous	**P4, P7**	Maintain scour holes under large woody debris and continue floodplain construction through vertical accretion and lateral migration of the channel

Compliance Point – Yackandandah Creek @ Osbornes Flat					***Gauge Number - 402204***	
Flow					***Rationale***	
Period	***Flow Type***	***Magnitude***	***Frequency***	***Duration***	***Objectives***	***Controlling Criteria***
Jun-Nov	High flow fresh	346ML/day	3/season (or natural)	3 days (or natural)	**M3b**	Achieve a phase shift in the shear stress distribution to export sands from pools
Jul-Sep	High flow fresh	346ML/day	2/season (or natural)	2 days (or natural)	**V1a**	High flows long enough to re-charge soil moisture in root zone of vegetation along top of bank. Retain a proportion of natural seasonal cumulative duration
Jul-Nov	High flow fresh	1904ML/day	1/season (or natural)	1 day (or natural)	**V1d**	Achieve overbank flooding
Jun-Nov	High flow fresh	1904ML/day	1/6yrs (or natural)	1 day (or natural)	**F4a**	Maintain natural periodicity of overbank or 'wetland filling' flows
Sep-Oct	High flow fresh	1904ML/day	1/5yrs (or natural)	1 day (or natural)	**V1c**	Recession to occur in spring
Jan-Dec	Fresh	259ML/day	3/yr (or natural)	3 days (or natural)	**P3**	Mobilise the gravel bed so pools etc can reform as channel migrates laterally
Jan-Dec	Fresh	350ML/day	4/yr (or natural)	2 days (or natural)	**P2, P5**	Achieve a phase shift in the shear stress distribution to export sands from pools and inundate benches to facilitate accretion and evolution of in-stream and floodplain features

Compliance Point – Yackandandah Creek @ Osbornes Flat					***Gauge Number - 402204***	
Flow					***Rationale***	
Period	***Flow Type***	***Magnitude***	***Frequency***	***Duration***	***Objectives***	***Controlling Criteria***
Jan-Dec	Fresh	1904ML/day	1/yr (or natural)	1 day (or natural)	**P6**	Maintain the competence of flows to scour bank material and for alluvial landforms to thereby evolve

Notes:

- The 'or natural' qualification on the low flow recommendation will ensure natural cease to flow frequency and duration in this reach. To meet objective V1b there shall be no increase in the aggregate duration and frequency of cease to flows to ensure that established trees do not suffer moisture stress during summer.
- A three day independence is recommended between events.
- Flow recommendations for each flow component do not have to be discrete. For example an overbank event recommended once every two years will also satisfy the requirement for a bankfull event and one of the high flow freshes.
- The controlling criteria relates to the objective that requires the highest flow to be achieved for the highest frequency and longest duration.
- Meeting the geomorphic objectives of P2 to P7 will be dependent on retaining the flow events specified for each objective and those flow events exceeding it.
- V3 requires further research in order to specify a flow recommendation, and is therefore omitted from Table 17 (refer Section 3.2.5).
- Yackandandah Creek is incised and, as a result, regular flood events do not inundate the floodplain. Where bankfull events have been prescribed on Yackandandah Creek the 1 year ARI has been used as an estimation of the discharge which previously reached the top of bank. Other studies have found the 1 year ARI event to be a reasonable approximation of the bankfull discharge (Leopold et al., 1964). Less frequent, higher discharge events are labelled as freshes and we have used other methods such as shear stress to calculate the discharge required to achieve the stated environmental objective.

- To achieve the hydraulic criteria for P1 (and hence M3a) we found that a low flow of 43 ML/day was required, a flow with a compliance of only 48% under the natural flow regime. The flow required to achieve the hydraulic criteria for P1 is dependent on the morphology of the pool and riffle sequence. As Yackandandah Creek has incised and bed form has not fully recovered from this disturbance, the flow required to achieve this recommendation is unduly influenced by a disturbance unrelated to the flow regime. Hence we have recommended that the 90th percentile low flow be used in the interim (16 ML/day). As the morphology of Yackandandah Creek recovers from past disturbance the hydraulic criteria for P1 should be reapplied to ascertain the flow required to meet this objective.

- There is a low compliance on the V2a and V2b recommendations for this reach (refer Appendix B for the flows derived). In both the low flow and high flow seasons there is rarely if ever extended periods with the 0.5-metre depth required to stress or drown terrestrial woody species establishing on bars. Hence, the V2a and V2b recommendations have not been retained for this reach as the hydraulic analysis undertaken on these objectives has demonstrated that these processes are not important on Yackandandah Creek. This indicates that over time Yackandandah Creek will be susceptible to the establishment of woody species on bars and potentially associated contraction of the channel.

- The V4 objective for this reach has not been included as a flow recommendation as the hydraulic criterion that achieves this objective is not well understood. A shear stress criterion trialled during the hydraulic investigations yielded unrealistic flow recommendations (refer Appendix B).

Table 18 Recommended average and maximum rates of rise and fall (expressed as the change in discharge of the event divided by the length of the event, ML/day/day)

Reach/Site	Period	Flow Component	Rate of Rise (ML/day/day)		Rate of Fall (ML/day/day)	
			AVE rate of rise	**MAX rate of rise**	**AVE rate of fall**	**MAX rate of fall**
Yackandandah Creek upstream of Sanatorium Road	Dec – May	Low flow fresh	186	1444	87	665
	Jun - Nov	High flow fresh	32	327	11	113

3. Supporting Recommendations

In order to achieve the overall visions set for each reach, a number of supporting recommendations (flow-related and non-flow related) are made alongside the environmental flow recommendations.

The flow-related recommendations include:

- Install a new compliance point;
- Investigate the influence of sub-surface flow on surface flow volumes; and
- Investigate the importance of low and high flows on the establishment and re-dispersal of Marsh Ludwigia.

The non-flow supporting recommendations include:

- Develop and implement a monitoring and evaluation program;
- Investigate the influence of de-silting operations at dams;
- Continue willow management;
- Continue the fencing of riparian zones;
- Stabilisation of cobble and gravel bars;
- Benchmarking in-channel vegetation;
- Management of sediment loads in the lower Kiewa River; and
- Facilitating the recovery of physical form on Running Creek and Yackandandah Creek

3.1 FLOW-RELATED SUPPORTING RECOMMENDATIONS

3.1.1 Install new compliance point

There are currently no functional gauges operating on Mountain Creek. A gauge formerly operated from 1966 to 1982, the Mountain Creek gauge at Coopers, gauge number 402207. Therefore it is recommended that a gauge be installed on this tributary to monitor the compliance of any flow regime implemented.

To address uncertainties regarding the impact of groundwater/surface water interaction on compliance between gauging stations there may also be the need to monitor low flows at set points within reaches, particularly on the Kiewa River. Such uncertainties regarding the validity of the hydrology along the Kiewa River should be addressed in the REALM study (SKM, 2007).

3.1.2 Investigate the influence of sub-surface flow on surface flow volumes

Our confidence in the low flow recommendations arising through use of the FLOWS method is diminished due to the potential impact of sub-surface flows in the Kiewa system. Sub-surface flows may mean that although sufficient water is passing through compliance points, sections of river within the reach, both upstream and downstream, may not be receiving this water as above-ground flow. As a result, the volume of water required to fill pools or provide a depth of flow over riffles, or meet any other hydraulic objective, may be greater than that suggested by the hydraulic modelling.

Further, unless the impact of sub-surface is quantified it cannot be confirmed whether addressing demand is addressing the environmental flow requirements of the Kiewa River. Water that is not extracted may be "lost" to sub-surface flows and hence not contribute the expected amount of water to environmental flow requirements throughout a reach.

3.1.3 Investigate the importance of low and high flows on the establishment and re-dispersal of Marsh Ludwigia

Marsh Ludwigia is an introduced amphibious macrophyte on the main stem of the Kiewa River and in Yackandandah and Running Creeks. In April 2007, it was observed growing in shallow (<5 cm deep) water at the channel margin and in moist silty-sandy interstices of cobble bars. It was present either as small but numerous individual plants (assumed to be seedlings) or as extensive mats, particularly in silty areas and backwaters.

An Australian experiment recognised Marsh Ludwigia as mildly invasive, based on its growth-nutrient responses, and therefore should be subject to precautionary control (Hastwell, Daniel & Vivian-Smith 2007). In 2005-2006, it was one of the most commonly recorded species in summer-connected wetlands between Albury and Barmah (Jane Catford, pers. comm.). Although its presence in the Ovens and Kiewa Rivers has been known for over 40 years (Aston 1967), it is not so well-known that Marsh Ludwigia has now spread downstream to wetlands on the Murray floodplain.

Information on Marsh Ludwigia is sparse. Flow objective V6 ('increase the abundance of native macrophytes in lowland reaches of the Kiewa River, and minimise the downstream expansion of introduced species') is aimed at the integrity of the in-channel macrophyte communities, which includes minimising Marsh Ludwigia. A flow process could not be specified for this objective as the potential role of the flow regime is unknown. Therefore it is recommended that an investigation into the importance of low flows and their timing on the establishment of Marsh Ludwigia be undertaken. High flows should be included in the study also, as these may have a role in scouring and re-dispersing the mats of Marsh Ludwigia that establish in autumn.

3.2 NON – FLOW RELATED SUPPORTING RECOMMENDATIONS

3.2.1 Develop and implement a monitoring and evaluation program

A monitoring program is recommended to assess whether the improvements or maintenance of processes expected from flow recommendations are in fact being achieved. If the objectives expected of the flow regime are not being achieved over time, the flow regime will require adjustment.

It is important to note that the capacity to alter flows in the Kiewa catchment is limited. Further, time frames for expected improvements in river condition may vary and in many cases improvements will not be immediate. In the same way that processes that lead to a degraded river system may occur over time frames ranging from days to years, the recovery of systems can take similar or even longer time frames.

The ability of a monitoring and evaluation program to identify ecological, geomorphic and water quality changes, quantify these changes, detect time frames expected and adjust actions accordingly will be critical to the adaptive management approach that is necessary for the environmental flow regime. The monitoring of how ecological objectives associated with the low flow are met should be the highest priority as these are likely to be most sensitive to changes in the flow regime and errors in the computations. The behaviour to be monitored is explained for each flow in the scientific justifications provided for all the objectives in the Issues Paper.

It is important to note that the Victorian EPA regularly sample the Kiewa Catchment for both water quality and invertebrates. Hence, there is a monitoring program that is already in place for at least some of the values. Any proposed monitoring and evaluation program should include a review of existing data to look for efficiencies and greater added value.

3.2.2 Investigate the influence of de-silting operations

It is recommended that a separate and dedicated evaluation be done on the de-silting operations at dams in the Kiewa Catchment, with the aim of determining the probable effects of such operations. The study could be undertaken in two parts: desktop and field.

The desktop component should involve compiling the history from as many sites within the Kiewa system as possible. This includes collating information on timing, frequency and duration of de-silting operations, daily flow and stage height data (actual data, not daily averages) for the same period, and all of the available water quality records (particularly temperature and turbidity). The purposes of the desktop study would be two-fold: documentation of the frequency, occurrence and downstream extent of effects on variables such as flow, stage and water quality; evaluation of effects on in-stream processes and biota.

The field study would be a field experiment, comparing before versus after at specific sites, and identifying empirically the downstream effect. This field component may include sampling water quality, including the quality of the silts in the pondage before release as well as during release. Other options for the field study are to examine the before and after condition of macro-invertebrates, fish abundance, biofilms and macrophytes; or to do a bio-assay, using artificial substrates.

Thus, this investigation is not proposed as the repetition of current monitoring programs. It is proposed as a scientific program of hypothesis testing, posing questions regarding the impacts of de-silting operations which may require some monitoring to answer. However, any monitoring only involves collecting information to the extent and for the time period required to answer the question.

3.2.3 Continue willow management

The continued management of willows in the Catchment is essential to achieving the reach visions, particularly in relation to achieving healthy riparian zones. Willows were observed in all reaches by the Technical Panel. To reduce the impact of willows on river health along the Kiewa River it is likely that an accelerated program of willow management will be required.

Willows in the riparian zone are known to have detrimental impacts on water quality and aquatic life and provide lower habitat values to riparian fauna. They also provide lower inputs of large wood into streams, a valuable source of habitat and food for in-stream fauna and influence the physical form of the river channel (Read and Barmuta, 1999, Greenwood et al., 2004, Pope et al., 2006).

3.2.4 Continue the fencing of riparian zones

Stock access, including stock crossing the river, can have a detrimental effect on water quality, can influence bank erosion and damage in-stream ecosystems. Managing stock access to the riparian zone is the key to achieving a healthy riparian zone.

While sections of the Kiewa River have been fenced, there are many areas where the health of the Kiewa River is affected by stock access. To have a significant impact on river health in the medium term an accelerated program of stock management and revegetation is required.

3.2.5 Stabilisation of cobble and gravel bars

A flow recommendation could not be assigned to flow objective V3 (‘limit the establishment of terrestrial woody perennials, especially non-native species in the family Salicaceae on cobble and gravel bars’) because more knowledge is required.

Cobble and gravel bars are shifting geomorphic features, being shaped and re-assembled by a range of flows, particularly high flows. They are also a special type of habitat for plant and animal species and therefore add to in-channel habitat diversity and make a specific contribution to regional aquatic and terrestrial bio-diversity. The importance of cobble and gravel bars is only beginning to be recognised (e.g. Framenau et al. 2002). Not only do cobble and gravel bars respond to floods, they also influence flood passage.

Catastrophic failure is associated with bars that have been fairly-well stabilised by woody riparian vegetation, whether native or non-native. Clearly, maintaining cobble and gravel bars at an early non-stabilised stage is desirable for river health. Conversely, the type of vegetation present may be a useful indicator of river health.

However, the stabilisation process facilitated by riparian vegetation is not well-understood. Critical information for river management is: Which are the woody species of interest and are these species the same throughout the catchment?

What time of the year and under what flow conditions do these woody species disperse and establish? What flow conditions allows them to persist and establish further? How fast do they grow and when do they reach a stage of being a significant hydraulic influence? Does silt accelerate the stabilisation process? Knowing the answers to these questions will become more important as flow patterns respond to the predictions for climate change.

3.2.6 Benchmarking in-channel vegetation

In-channel vegetation has many ecological roles so it is especially important for river health. In-channel vegetation contributes to in-stream production by its growth and as a substrate for biofilms. It also helps to stabilise river banks and contributes to habitat diversity for macro-invertebrates and small fish. Despite its important influence, there is no information available other than incidental observations regarding the occurrence of vegetation in the channel and on its banks. This is a major knowledge gap that constrains the value of flow recommendations.

A survey to benchmark in-channel vegetation is recommended, focusing on amphibious, emergent and submerged macrophytes occurring on the channel floor and bank. This should use a reach-based stratified design, and aim to establish a baseline description of the distribution and abundance of species and functional types in relation to environmental factors, selected to challenge a multi-hypothesis based approach. This would be a two-season survey of in-channel vegetation (spring and autumn), that would need to account for antecedent conditions in the interpretations. As this is a fairly standard type of plant ecology (standard but not conducted in streams), the study would be best progressed by a post-graduate student. Therefore it is recommended that the CMA sponsor or support a post-graduate student for this work, and that the outcome be some hypotheses or models explaining species or functional groups from upland to lowland for the Kiewa River and major tributaries within the sampling time.

Environmental relationships and dynamics of in-channel vegetation are a challenging area, and are the focus of limited research elsewhere within Australia. This study will provide the basic information that will make it easier to apply research findings to the Kiewa River and its tributaries and so provide an informed context for river management.

3.2.7 Management of sediment loads in the lower Kiewa River

The bed, bar and bench morphology of the lower Kiewa River is adversely affected by the transport of sand from Yackandandah Creek. This change in morphology is reducing the availability of pool habitat and coarse gravel benthic habitat in the lower Kiewa River.

The morphology of the lower Kiewa River indicates that the rate of sand export from Yackandandah Creek and the middle Kiewa River exceeds the transport capacity of the lower Kiewa River. The provision of environmental flows on the Kiewa River may export some of the additional sand load from the lower Kiewa River but is unlikely to resolve the issue.

Sediment loads in the lower Kiewa River may best be managed by reducing the influx of sediment from Yackandandah Creek. Management intervention to reduce the sediment load from Yackandandah Creek should focus on the hydraulic aspects of the channel that dictate the capacity of a stream to transport sediment. Hydraulic modelling will assist in determining the most appropriate focus for sediment management works.

3.2.8 Facilitating the recovery of physical form on Running Creek and Yackandandah Creek

The physical form of both Running Creek and Yackandandah Creek has been altered markedly from the natural state. The main cause of this change in physical form has been incision, although, in the case of Yackandandah Creek, the changes to the system are more dramatic and encompass the flushing of cohesive sediments from floodplain material, the anthropogenic movement of the channel across the valley floor and the construction of levees on the floodplain.

This altered physical form, by its nature, changes the flow magnitudes that achieve the environmental objectives. Hence, flow recommendations can reflect the altered morphology rather than flow requirements.

It is recommended that actions be implemented to facilitate the recovery of physical form on Running Creek and Yackandandah Creek. Due to the nature of physical changes to the creeks this recovery process will be slow and will largely rely on the restoration of riparian vegetation and the subsequent natural construction of bars and benches, rebuilding the channel form.

3.3 CONCLUSION

Recommendations presented in this report identify the flow regime required to meet environmental objectives for the protection, improvement or maintenance of ecological and geomorphic assets and processes on the Kiewa River and tributaries. The recommendations have been developed by the Technical Panel utilising the FLOWS method. In particular the recommendations are based on satisfying ecological requirements for fish, macroinvertebrates, riparian vegetation, water quality, and geomorphology, as determined by the Technical Panel.

Analysis of non-flow related options to improve river health has not been the focus of this report and will need to be addressed in future management plans for the Kiewa catchment. The focus of this report has been identifying flow regime requirements for ecological health, and not the social or economic impacts of implementing these recommendations.

The report will function as an input into the development of a Streamflow Management Plan for the Kiewa River and its tributaries. The results of this process (environmental flow requirements), and additional information, such as community water demands, will be utilised in the decision making process of determining future water allocation along the Kiewa River and its catchment for various environmental and consumptive uses.

4. Flow Recommendation Comparison

4.1 DEFINITIONS

The flow recommendation comparison presented herein aims to give an appreciation of how our flow recommendations compare to the natural and current flow regimes. We have calculated the degree of compliance to our recommendations that would be achieved under the **natural** and **current** flow regimes in accordance with the following methodologies.[3] The definitions of the natural and current flow regimes provided by SKM (2007) are given below.

The **natural** flow regime refers to the scenario where all direct anthropogenic impacts on streamflows have been removed. That is, the effects of farm dams, private diversions, urban diversions, the hydro-electric scheme and other impoundments have been removed from the hydrologic model. However, changes in streamflow due to land use changes over time (eg. land clearing) have not been taken into account.

The **current** flow regime refers to the existing level of development in the Kiewa Basin. For the purposes of defining irrigation demands, 2005/06 was the last full irrigation season for which data was available for SKM (2007), and so their calculation of current irrigation was based on this season. This was the final year of tobacco irrigation in the Kiewa and Ovens valleys, so tobacco is assumed to exist in the current scenario used here.

Magnitude compliance

For high and low flows we have based the compliance on the percentage of days within the specified flow season that the minimum flow rate was met or exceeded. Hence, if for example the minimum high flow over winter and spring was met on 135 days of the 183 days in this period (June to November inclusive) then compliance is calculated as 135/183 x 100 = 73%

For event based flows such as freshes, bankfull and overbank events, compliance was based on whether the specified flow rate occurred in the flow period, regardless of frequency and duration recommendations. For example, if the recommended flow for a summer fresh was 80ML/d and this was met or exceeded at least once in 36 years out of a 40 year daily flow record then the percentage flow rate compliance for the summer fresh would be 36/40 x 100 = 90%.

[3] The level of compliance of the flow recommendations for the natural and current flow regime presented in the following tables is an underestimation due to the presence of the 'or natural' clause in the recommendations. As discussed earlier, the 'or natural' clause on the low flow and high flow recommendations indicate that flow is recommended to be equal to or above the value specified for that season except when flows ***naturally*** fall below that value. For the freshes and larger events, the 'or natural' clause refers to the frequency and duration of the event. That is, the event occurs for the duration and frequency specified unless the particular event would be ***naturally*** less frequent or of a shorter duration.

Magnitude and frequency compliance

Frequency compliance was calculated as the percentage of years in the flow record when the recommended number, or frequency, of a specified event occurred, regardless of duration. Hence, if three winter freshes were recommended and at least three winter freshes exceed the flow rate in 24 years out of a 40 year record then the percentage frequency compliance is 24/40 x 100 = 60%. Events were determined based on a three day independence.

Where a flow event is not required every year the number of flow events are counted over a longer time period than just one season. For example, when a flow event is required once every five years, or in 20% of the years, then if the event occurs in 15% of the years of record the compliance is 15/20 x 100 = 75%.

Magnitude, frequency and duration compliance

Volume compliance was calculated as the percentage of years in the flow record when events of the recommended flow rate, frequency and duration occurred. Hence, if three winter freshes were recommended of seven days duration and at least three winter freshes of seven or more days duration exceeded the specified minimum flow rate in 16 years out of a 40 year record then the percentage duration compliance is 16/40 x 100 = 40%.

Where two events exceed the flow rate threshold, but are not independent (not more than 3 days apart), then the duration of the event is the total number of days for which the flow rate threshold is exceeded.

To make the compliance tables easier to read we have colour coded the columns indicating the degree of compliance to our recommendations based on the following legend.

LEGEND				
Mostly Complies		Greater than	95%	of time/years/events
Frequently Complies		Between	76 & 95%	of time/years/events
Often Complies		Between	51 & 75	of time/years/events
Occasionally Complies		Between	26 & 50%	of time/years/events
Rarely Complies		Between	5 & 25%	of time/years/events
Never Complies		Between	0 & 5%	of time/years/events

4.2 DISCUSSION OF THE COMPLIANCE RESULTS

There are a number of ways to analyse the compliance results provided for each reach of the Kiewa FLOWS study in Sections 4.3 to 4.8. One perspective is to use the compliance numbers to examine the degree to which changes to stream flows, from the natural flow regime, have altered the occurrence of the flow recommendations. The change in the natural occurrence of flow events can be judged by looking at how different the compliance of a recommendation is under the current flow regime relative to the natural flow regime. If the compliance, or the percentage of time for which a flow regime occurs, is lower under the current flow regime relative to natural then the results suggest that anthropogenic influences such as farm dams, private diversions, urban diversions and the hydro-electric scheme have changed the occurrence of an environmentally significant flow.

If we examine the compliance results down the reaches of the Kiewa River (reaches 1, 2 and 3) we can see that anthropogenic influences have had quite a consistent impact on the occurrence of recommended flow events. For low flows in reaches 1, 2 and 3 the compliance under the current flow regime is only slightly lower than that under natural, 1%, 2% and 2% respectively (Table 19-Table 21). Furthermore, for high flows and the smaller fresh events the compliance under the current flow regime has not decreased relative to natural on the three reaches of the Kiewa and in two cases has actually increased[4]. However, there has been a noticeable reduction in the compliance of larger fresh, bankfull and overbank events along the reaches of the Kiewa River. In Reach 1 the occurrence of these fresh events has reduced by around 15% (23%)[5] with the impact dropping to around 5% to 10% (8% to 15%) in Reaches 2 and 3.

Overall these results suggest that the current flow regime on the main stem of the Kiewa River already provides for the environmental assets that are dependent on low flows, high flows and the smaller fresh events. It is speculated that the hydro releases are increasing the occurrence of small freshes, or at least partially compensating for the adverse effect of other anthropogenic changes to freshes, such as the impact of farm dams. However, it is further speculated that the larger storages in the catchment are adversely impacting the occurrence of larger fresh events on the main stem of the Kiewa River. This adverse impact on larger freshes dissipates or decreases downstream, probably due to flow routing or storage effects. Thus, environmental assets dependent on the occurrence of larger freshes, bankfull and overbank events may, particularly in the upstream reaches, be impacted under the current flow regime.

In the tributaries of the Kiewa River, Mountain Creek, Running Creek and Yackandandah Creek, the compliance calculations indicate that the current flow regime is little changed from natural. Hence, under current conditions the flow requirements of environmental assets in these tributaries are largely met. The possible exception to this generalisation is the low flow recommendation for Running Creek. The compliance of this low flow recommendation is 6% (13%) lower under the current flow regime relative to natural. Thus, further diversions on Running Creek during the low flow season may start to impact on environmental assets.

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[4] Note, in this discussion we are only examining the full compliance of fresh type events. That is, we are only comparing the magnitude, frequency and duration compliance of freshes under natural and current flow regimes. The magnitude compliance and magnitude & frequency compliance are useful for determining which criterion (magnitude, frequency or duration) is having the greatest influence on compliance, but these numbers do not include all criteria and hence do not fully represent a flow recommendation.

[5] The percentage given outside the brackets is the change in compliance shown in the compliance tables (e.g. Table 19). The percentage in the brackets is this same change in compliance but as an approximate proportion of the natural compliance. Thus the percentage in the brackets reflects the fact that if compliance is low under natural conditions then any reduction in the absolute compliance under current conditions is more significant.

4.3 REACH ONE: UPPER KIEWA RIVER

Note: the compliance for Reach One (Table 19) was based on the Mongans Bridge gauge (402203) upstream of the site and the flow recommendations given in Table 2.

It is important to note that the compliance for a particular flow regime, for instance the low flow, can vary between reaches (e.g. compare Table 19 and Table 20). This may be because the environmental objective that is controlling the flow recommendation is different in each reach. The controlling objectives are highlighted in Section 2. Even when the controlling objectives are the same for two different reaches, these objectives specify a hydraulic criterion that needs to be met, the flow recommendation is then determined from the hydraulic criterion. Hence two reaches may require the same depth or velocity of flow to satisfy the same environmental objective, however, the different geometry of these reaches will mean that this depth or velocity is provided by different flow magnitudes in each reach.

Table 19 Compliance of flow recommendations to natural and current flow regimes for Reach One

Component	*Months*	*Flow Rec (ML/d)*		*Or Natural*[6]	*Natural Compliance*[7]	*Current Compliance*[8]
Low flow	Dec-May	Magnitude	259	Yes	71%	70%
High flow fresh	Jul-Nov	Magnitude	8122		58%	45%
		Magnitude & Frequency		Yes	58%	45%
		Magnitude & Frequency & Duration		Yes	58%	45%
Fresh	Jan-Dec	Magnitude	6480		78%	63%
		Magnitude & Frequency		Yes	78%	63%
		Magnitude & Frequency & Duration		Yes	78%	63%

[6] Indicates that flow is recommended to be equal to or above the value specified for that season except when flows ***naturally*** fall below that value. For the freshes and larger events, the 'or natural' clause refers to the frequency and duration of the event. That is, the event occurs for the duration and frequency specified unless the particular event would be ***naturally*** less frequent or of a shorter duration. The 'Yes' in the table and all subsequent tables refers to where the 'or natural' clause (defined in Section 2) applies and the blacked out square to where it does not apply. That is, the 'or natural' clause can only be applied to flow magnitudes when the flows are continuous.

[7] Compliance under the natural flow regime.

[8] Compliance under the current flow regime.

Component	*Months*	*Flow Rec (ML/d)*		*Or Natural*[6]	*Natural Compliance*[7]	*Current Compliance*[8]
Fresh	Jan-Dec	Magnitude	8122		60%	48%
		Magnitude & Frequency		Yes	60%	48%
		Magnitude & Frequency & Duration		Yes	60%	48%
Fresh	Jan-Dec	Magnitude	30240		100%	0%[9]
		Magnitude & Frequency		Yes	100%	0%
		Magnitude & Frequency & Duration		Yes	100%	0%

[9] This fresh has a 20-year average recurrence interval and there are only two of these events in the hydrologic record (approximately 40-years long). The current regime indicates that the two events that exceeded the 30,240 ML/day threshold under natural flows would have flow rates below this threshold under current conditions giving 0% compliance. In reality some of these high flow events would occur in a longer record of the current flow regime, they would just have higher average recurrence intervals than 20-years.

4.4 REACH TWO: MIDDLE KIEWA RIVER

Note: the compliance for Reach Two (Table 20) was based on the gauges Kiewa River @ Kiewa (Main Stem) and Kiewa River @ Kiewa (Anabranch) and the flow recommendations given in Table 5.

Table 20 Compliance of flow recommendations to natural and current flow regimes for Reach Two

Component	*Months*	*Flow Rec (ML/d)*		*Or Natural*	*Natural Compliance*	*Current Compliance*
Low flow	Dec-May	Magnitude	346	Yes	61%	59%
Low flow fresh	Dec-Apr	Magnitude	605		100%	100%
		Magnitude & Frequency		Yes	98%	100%
		Magnitude & Frequency & Duration		Yes	78%	78%
High flow	Jun-Nov	Magnitude	1184	Yes	76%	78%
High flow fresh	Jul-Sep	Magnitude	3888		90%	85%
		Magnitude & Frequency		Yes	83%	78%
		Magnitude & Frequency & Duration		Yes	68%	60%
Bankfull	Jul-Sep	Magnitude	6048		78%	68%
		Magnitude & Frequency		Yes	78%	68%
		Magnitude & Frequency & Duration		Yes	60%	55%
Overbank	Jun-Nov	Magnitude	6912		78%	73%
		Magnitude & Frequency		Yes	78%	73%
		Magnitude & Frequency & Duration		Yes	75%	65%
Overbank	Sep-Oct	Magnitude	6912		100%	100%
		Magnitude & Frequency		Yes	100%	100%
		Magnitude & Frequency & Duration		Yes	100%	100%

Component	*Months*	*Flow Rec (ML/d)*		*Or Natural*	*Natural Compliance*	*Current Compliance*
Overbank	Jul-Dec	Magnitude	6912		73%	70%
		Magnitude & Frequency		Yes	73%	70%
		Magnitude & Frequency & Duration		Yes	70%	65%
Overbank	Jul-Nov	Magnitude	6912		73%	70%
		Magnitude & Frequency		Yes	73%	70%
		Magnitude & Frequency & Duration		Yes	70%	65%
Fresh	Jan-Dec	Magnitude	1728		100%	100%
		Magnitude & Frequency		Yes	88%	98%
		Magnitude & Frequency & Duration		Yes	68%	75%
Overbank	Jan-Dec	Magnitude	5616	Yes	90%	83%
		Magnitude & Frequency		Yes	80%	65%
		Magnitude & Frequency & Duration		Yes	68%	60%
Bankfull	Jan-Dec	Magnitude	6912		78%	73%
		Magnitude & Frequency		Yes	78%	73%
		Magnitude & Frequency & Duration		Yes	78%	73%

4.5 REACH THREE: LOWER KIEWA RIVER

Note: the compliance for Reach Three (Table 21) was based on the Kiewa River @ Bandiana gauge (402205) and the flow recommendations given in Table 8.

Table 21 Compliance of flow recommendations to natural and current flow regimes for Reach Three

Component	*Months*	*Flow Rec (ML/d)*		*Or Natural*	*Natural Compliance*	*Current Compliance*
Low flow	Dec-May	Magnitude	432	Yes	55%	53%
High flow	Jun-Nov	Magnitude	1287	Yes	76%	75%
High flow fresh	Jul-Sep	Magnitude	2592		95%	95%
		Magnitude & Frequency		Yes	85%	90%
		Magnitude & Frequency & Duration		Yes	83%	83%
Overbank	Sept-Oct	Magnitude	5184		100%	100%
		Magnitude & Frequency		Yes	100%	100%
		Magnitude & Frequency & Duration		Yes	100%	100%
Overbank	Jun-Nov	Magnitude	5184		93%	85%
		Magnitude & Frequency		Yes	93%	85%
		Magnitude & Frequency & Duration		Yes	63%	55%
Overbank	Jul-Dec	Magnitude	5184		88%	85%
		Magnitude & Frequency & Duration		Yes	88%	85%
		Magnitude & Frequency & Duration		Yes	73%	73%
Bankfull	Jul-Sep	Magnitude	4320		88%	80%
		Magnitude & Frequency		Yes	88%	80%
		Magnitude & Frequency & Duration		Yes	75%	68%

Component	*Months*	*Flow Rec (ML/d)*		*Or Natural*	*Natural Compliance*	*Current Compliance*
Bankfull	Jan-Dec	Magnitude	3024		98%	98%
		Magnitude & Frequency		Yes	83%	83%
		Magnitude & Frequency & Duration		Yes	65%	55%
Overbank	Jan-Dec	Magnitude	4628		93%	85%
		Magnitude & Frequency		Yes	90%	78%
		Magnitude & Frequency & Duration		Yes	68%	58%

4.6 REACH FOUR: MOUNTAIN CREEK

Note: the compliance for Reach Four (Table 22) was based on the Mountain Creek @ Coopers gauge (402207) and the flow recommendations given in Table 11.

Table 22 Compliance of flow recommendations to natural and current flow regimes for Reach Four

Component	*Months*	*Flow Rec (ML/d)*		*Or Natural*	*Natural Compliance*	*Current Compliance*
Low flow	Dec-May	Magnitude	17	Yes	88%	87%
Low flow fresh	Dec-Apr	Magnitude	130		40%	40%
		Magnitude & Frequency		Yes	40%	40%
		Magnitude & Frequency & Duration		Yes	40%	40%
High flow	Jun-Nov	Magnitude	58	Yes	76%	76%
Overbank	Jul-Nov	Magnitude	173		88%	88%
		Magnitude & Frequency		Yes	65%	65%
		Magnitude & Frequency & Duration		Yes	60%	60%
Fresh	Jan-Dec	Magnitude	147		95%	95%
		Magnitude & Frequency		Yes	85%	85%

Component	*Months*	*Flow Rec (ML/d)*		*Or Natural*	*Natural Compliance*	*Current Compliance*
		Magnitude & Frequency & Duration		Yes	65%	65%
Bankfull	Jan-Dec	Magnitude	173		90%	90%
		Magnitude & Frequency		Yes	90%	90%
		Magnitude & Frequency & Duration		Yes	83%	83%
Overbank	Jan-Dec	Magnitude	346		58%	58%
		Magnitude & Frequency		Yes	58%	58%
		Magnitude & Frequency & Duration		Yes	58%	58%

4.7 REACH FIVE: RUNNING CREEK

Note: the compliance for Reach Five (Table 23) was based on the Running Creek @ Running Creek gauge (402206) and the flow recommendations given in. Table 14

Table 23 Compliance of flow recommendations to natural and current flow regimes for Reach Five

Component	*Months*	*Flow Rec (ML/d)*		*Or Natural*	*Natural Compliance*	*Current Compliance*
Low flow	Dec-May	Magnitude	26	Yes	48%	42%
Low flow fresh	Dec-Apr	Magnitude	130		40%	40%
		Magnitude & Frequency		Yes	40%	40%
		Magnitude & Frequency & Duration		Yes	40%	40%
High flow	Jun-Nov	Magnitude	47	Yes	73%	72%
High flow fresh	Jul-Nov	Magnitude	467	Yes	58%	58%
		Magnitude & Frequency		Yes	58%	58%
		Magnitude & Frequency &		Yes	50%	50%

Component	*Months*	*Flow Rec (ML/d)*		*Or Natural*	*Natural Compliance*	*Current Compliance*
		Duration				
High flow fresh	Jul-Sep	Magnitude	518		95%	95%
		Magnitude & Frequency		Yes	95%	95%
		Magnitude & Frequency & Duration		Yes	95%	95%
High flow fresh	Jun-Nov	Magnitude	1123		68%	68%
		Magnitude & Frequency		Yes	68%	68%
		Magnitude & Frequency & Duration		Yes	53%	53%
High flow fresh	Sep-Oct	Magnitude	467		100%	100%
		Magnitude & Frequency		Yes	100%	100%
		Magnitude & Frequency & Duration		Yes	100%	100%
Fresh	Jan-Dec	Magnitude	346		83%	83%
		Magnitude & Frequency		Yes	83%	83%
		Magnitude & Frequency & Duration		Yes	63%	63%
Fresh	Jan-Dec	Magnitude	518		55%	55%
		Magnitude & Frequency		Yes	55%	55%
		Magnitude & Frequency & Duration		Yes	55%	55%
Fresh	Jan-Dec	Magnitude	1123		68%	68%
		Magnitude & Frequency		Yes	68%	68%
		Magnitude & Frequency & Duration		Yes	68%	68%

4.8 REACH SIX: YACKANDANDAH CREEK

Note: the compliance for Reach Six (Table 24) was based on the Yackandandah Creek @ Osbornes Flat (402204) and the flow recommendations given in Table 17.

Table 24 Compliance of flow recommendations to natural and current flow regimes for Reach Six

Component	*Months*	*Flow Rec (ML/d)*		*Or Natural*	*Natural Compliance*	*Current Compliance*
Low flow	Dec-May	Magnitude	16	Yes	90%	90%
High flow	Jun-Nov	Magnitude	65	Yes	76%	74%
High flow fresh	Jun-Nov	Magnitude	346		95%	95%
		Magnitude & Frequency		Yes	85%	85%
		Magnitude & Frequency & Duration		Yes	55%	55%
High flow fresh	Jul-Sep	Magnitude	346		88%	88%
		Magnitude & Frequency		Yes	83%	83%
		Magnitude & Frequency & Duration		Yes	75%	75%
High flow fresh	Jul-Nov	Magnitude	1904		60%	60%
		Magnitude & Frequency		Yes	60%	60%
		Magnitude & Frequency & Duration		Yes	60%	60%
Fresh	Jun-Nov	Magnitude	1904		100%	100%
		Magnitude & Frequency		Yes	100%	100%
		Magnitude & Frequency & Duration		Yes	100%	100%
Fresh	Sep-Oct	Magnitude	1904		100%	100%
		Magnitude & Frequency		Yes	100%	100%

Component	*Months*	*Flow Rec (ML/d)*		*Or Natural*	*Natural Compliance*	*Current Compliance*
		Magnitude & Frequency & Duration		Yes	100%	100%
Fresh	Jan-Dec	Magnitude	259		98%	98%
		Magnitude & Frequency		Yes	90%	88%
		Magnitude & Frequency & Duration		Yes	70%	70%
Fresh	Jan-Dec	Magnitude	350		95%	95%
		Magnitude & Frequency		Yes	78%	78%
		Magnitude & Frequency & Duration		Yes	63%	60%
Fresh	Jan-Dec	Magnitude	1904		65%	65%
		Magnitude & Frequency		Yes	65%	65%
		Magnitude & Frequency & Duration		Yes	65%	65%

5. References

Aston, H. I. (1967). Aquatic angiosperms: records of four introduced species new to Victoria. *Muelleria* 1: 169-174.

Biggs, B. J. F (1996). Hydraulic habitat of plants in streams. *Regulated Rivers: Research and Management* 12: 131-144.

DNRE (2002) *The FLOWS Method - A Method for Determining Environmental Water Requirements in Victoria,* Department of Natural Resources and Environment, Victoria.

Earth Tech (2007a) *Environmental Flow Determination for the Kiewa River – Issues Paper,* Unpublished Report to North East Catchment Management Authority by the Kiewa River Environmental Flow Determination Technical Panel.

Earth Tech (2007b) *Environmental Flow Determination for the Kiewa River – Site Paper,* Unpublished Report to North East Catchment Management Authority by the Kiewa River Environmental Flow Determination Technical Panel.

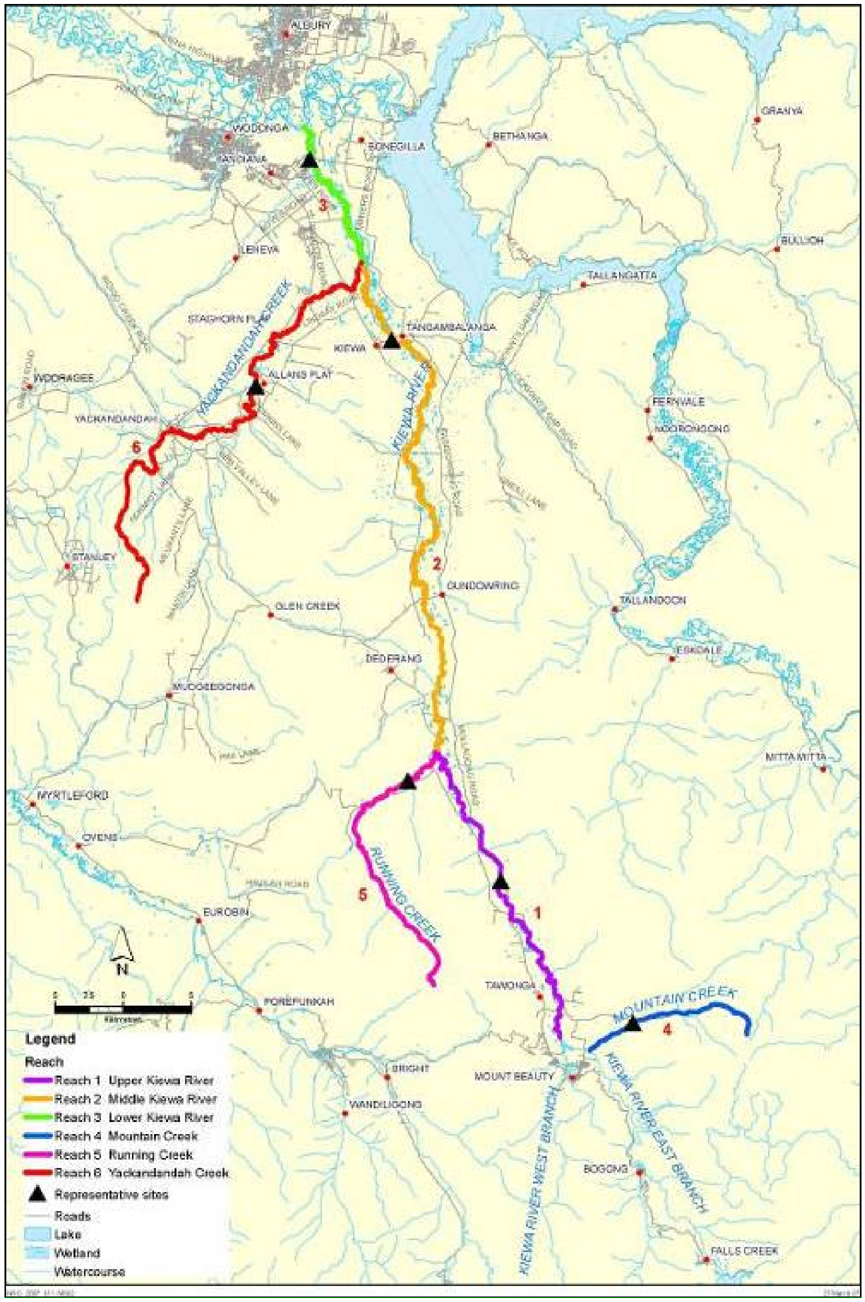
Framenau, V.W., Manderbach, R. and Baehr, M. (2002). Riparian gravel banks of upland and lowland rivers in Victoria (south-east Austalia): arthropod community structure and life history patterns along a longituidnal gradient. *Australian Journal of Zoology* 50: 103-123.

Hastwell, G. T., Daniel, A. J. and Vivian-Smith, G. (2007). Predicting invasiveness in exotic species: do subtropical native and invasive exotic aquatic plants differ in their growth responses to macronutrients? *Diversity and Distributions* (in press).

SKM (2007). *Kiewa River Environmental Flows: Update of REALM Model and Derivation of Daily Flows* (final). Sinclair Knight Merz Pty. Ltd., Melbourne.

Appendix A

Catchment Map


ALBURY
WODONGA
BONEGILLA
BETHANGA
GRANYA
BULLIOH
TALLANGATTA
LENEVA
STAGHORN FLAT
KIEWA
TANGAMBALANGA
ALLANS FLAT
WOORAGEE
YACKANDANDAH
YACKANDANDAH CREEK
KIEWA RIVER
FERNVALE
NOORONGONG
STANLEY
GUNDOWRING
GLEN CREEK
TALLANDOON
ESKDALE
DEDERANG
MUDGEEGONGA
MITTA MITTA
MYRTLEFORD
OVENS
RUNNING CREEK
EUROBIN
TAWONGA
POREPUNKAH
MOUNTAIN CREEK
BRIGHT
MOUNT BEAUTY
WANDILIGONG
KIEWA RIVER WEST BRANCH
KIEWA RIVER EAST BRANCH
BOGONG
FALLS CREEK
N
1
2
3
4
5
6
Legend
Reach
Reach 1 Upper Kiewa River
Reach 2 Middle Kiewa River
Reach 3 Lower Kiewa River
Reach 4 Mountain Creek
Reach 5 Running Creek
Reach 6 Yackandandah Creek
Representative sites
Roads
Lake
Wetland
Watercourse

Appendix B

Summary of hydrologic or hydraulic measures used to develop flow recommendations