Barwon Water

Barham River – Environmental flow study

Final

August 2003

SINCLAIR KNIGHT MERZ

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Sinclair Knight Merz Pty Limited
ACN 001 024 095
ABN 37 001 024 095
590 Orrong Road
Armadale VIC 3143
PO Box 2500
Malvern VIC 3144
Australia
Telephone: +61 3 9248 3100
Facsimile: +61 3 9248 3364

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1. Introduction

Barwon Water is the water authority responsible for servicing Apollo Bay, Skenes Creek and Marengo. The town of Apollo Bay, on the south west coast of Victoria, is supplied with water from the Barham River via an annual bulk entitlement of 365 ML. During the last three summers, this entitlement has lead to limitations to the availability of water for this town. Therefore to reduce the likelihood of future water shortages, Barwon Water intends applying to the Department of Sustainability and Environment (DSE) to increase the annual bulk water entitlement to 600ML. To achieve an entitlement of this magnitude, the point of extraction from the river must be moved further downstream to provide greater water yield. The extraction of a greater volume of water may potentially increase the impact on the aquatic environment. An environmental flow assessment is proposed to assess and minimise the impact that this, the sole extraction from the Barham River, has on the freshwater reach of the river downstream of the point of extraction.

DSE has developed the Victorian Water for the Environment Program to implement measures that provide water to meet environmental needs. The objective of this program is to increase environmental flows to maintain and, where possible, restore the environmental values of rivers and wetlands, whilst recognising existing entitlements. The program includes a two-stage process for providing water for the environment that involves:

- protecting and enhancing environmental flows through water entitlement agreements; and
- rehabilitating stressed river systems (NRE, 1997).

The project was conducted in two distinct stages. Stage 1 involved a review of available information on the environmental status of the catchment with respect to ecology, hydrology, geomorphology and water quality. Stage 2 included undertaking a more detailed study in order to develop recommendations for the environmental water requirements of the Barham River in the project area. Specifically, the detailed environmental flow recommendations were documented along with the justification for the selection of the magnitude, duration and frequency for the site.

2. Study method

The study method utilised for the determination of environment flows for the Barham River was the recently developed FLOWS method (NRE, 2002a). A brief description of the method applied to this project area is provided below. The full method and rationale is presented in NRE (2002a).

The first stage of this project was to collect and collate all available information relating to the project area. This information was collected from a variety of sources including documented and anecdotal information. In addition, the project team utilised the knowledge and data available from the relevant stakeholders and the project group, which included members of the community, and representatives of DSE, Southern Rural Water, Environment Victoria and Corangamite Catchment Management Authority.

Utilising the information collected on the values and threats in the project area, a site visit was conducted to select a site that was representative of a range of hydrological, ecological and geomorphological features of the river. This was done using a technical panel with relevant ecological and geomorphological expertise. The technical panel comprised Michael Lake (ecologist), Gabrielle Pistone (Project Manager and ecologist) and Bruce Abernethy (geomorphologist). The site visit was also conducted to verify existing information and collect further information specific to the project area. The information collected on the values and threats to the system was documented in an Issues Paper (SKM, 2003).

At the selected site a series of standard descriptive tasks were undertaken. During this stage, the locations of cross-sections at the site were identified (6) for subsequ ent surveying. Six cross sections were pegged at the site using a single peg located on one bank. These cross sections were selected to be representative of site features in area of key habitats as identified across the relevant disciplines.

Following the pegging of all cross sections, each cross section was drawn and flow components identified. The cross sections were drawn to identify key features of ecological or structural relevance within the section and the flow components were identified that are specific for that particular reach of the river. The flow bands are components of the flow regime that are considered structurally or ecologically important for the ecosystem. These components were described hydrologically (duration and frequency) as well as the specific ecosystem function that they fill.

All cross sections identified were surveyed for inclusion into a hydraulic model. The survey was conducted using a total station to indicate any significant changes in channel shape, stream flows and habitat structure. All cross sections within a site were then linked to each other to indicate the slope and meanders of the river at that site. Water level was recorded at all sites to assist in validation of the hydraulic model.

A hydraulic model was prepared to develop a relationship between stream flow, and water level and velocity for each site. The hydraulic analysis of the sites was undertaken using the HEC-RAS software, which is designed to perform one-dimensional steady state calculations for a full network of natural and constructed channels or a single river reach. Separate hydraulic models were constructed for each of the sites using the surveyed cross sections. These models were then validated over a range of flows from minor to bankfull discharges.

Each model was then validated by undertaking a sensitivity analysis of the channel roughness represented by Manning's 'n' values and by adjusting the downstream boundary condition. As there was little or no data available for calibration it was necessary to assign textbook Manning's 'n' values for channel roughness. Appropriate values were then selected based on photographs and the site visit.

Additionally, a sensitivity analysis was undertaken by adjusting Manning's 'n'. Model outputs showed the variation in total depth for the range of Manning's values tested. The sensitivity of the model to the downstream condition was also assessed to determine the impact on calculated results. A range of flows were routed through the model that represented the full range of flows up to bankfull.

A daily flow series was developed through an associated project for both current and natural flows (SKM, 2003). Hydrological assessment involved consideration of a range of hydrological parameters to describe the flow regime, including:

- flow duration curves to examine the percentage of time that a flow of a given size is exceeded;
- time series graphs to examine the sequence of flow events, particularly during very dry or very wet conditions; and
- Get Spells analysis to describe flow spells (flow events above or below a defined threshold).

Key flow indicators were extracted from this information, such as mean and median flow, and suitable high and low flow indices such as the flow exceeded 20% and 80% of the time.

The analysis of the outputs and development of the recommendations was done by the technical panel. The recommendations were aimed at meeting the environmental values identified in the Issues Paper. Recommendations have been developed that describe the entire flow regime, not solely a minimum flow over a defined period. This document presents the recommendations and the justification for these.

3. Catchment description

The Barham River drains into Mounts Bay between Apollo Bay and Marengo (Figure 3.1). The Barham River has two major branches, the West Branch and East Branch. Both rise in the heavily forested catchment of the Otway Ranges. The West Barham Catchment is heavily forested and contains 1,050 hectares of native vegetation (Barwon Water, 2001). All land within the West Barham catchment is classified as State Forest. The lower section of the East Barham Catchment consists mainly of freehold land. There is some Crown Land in the upper catchment (Barwon Water, 2001).

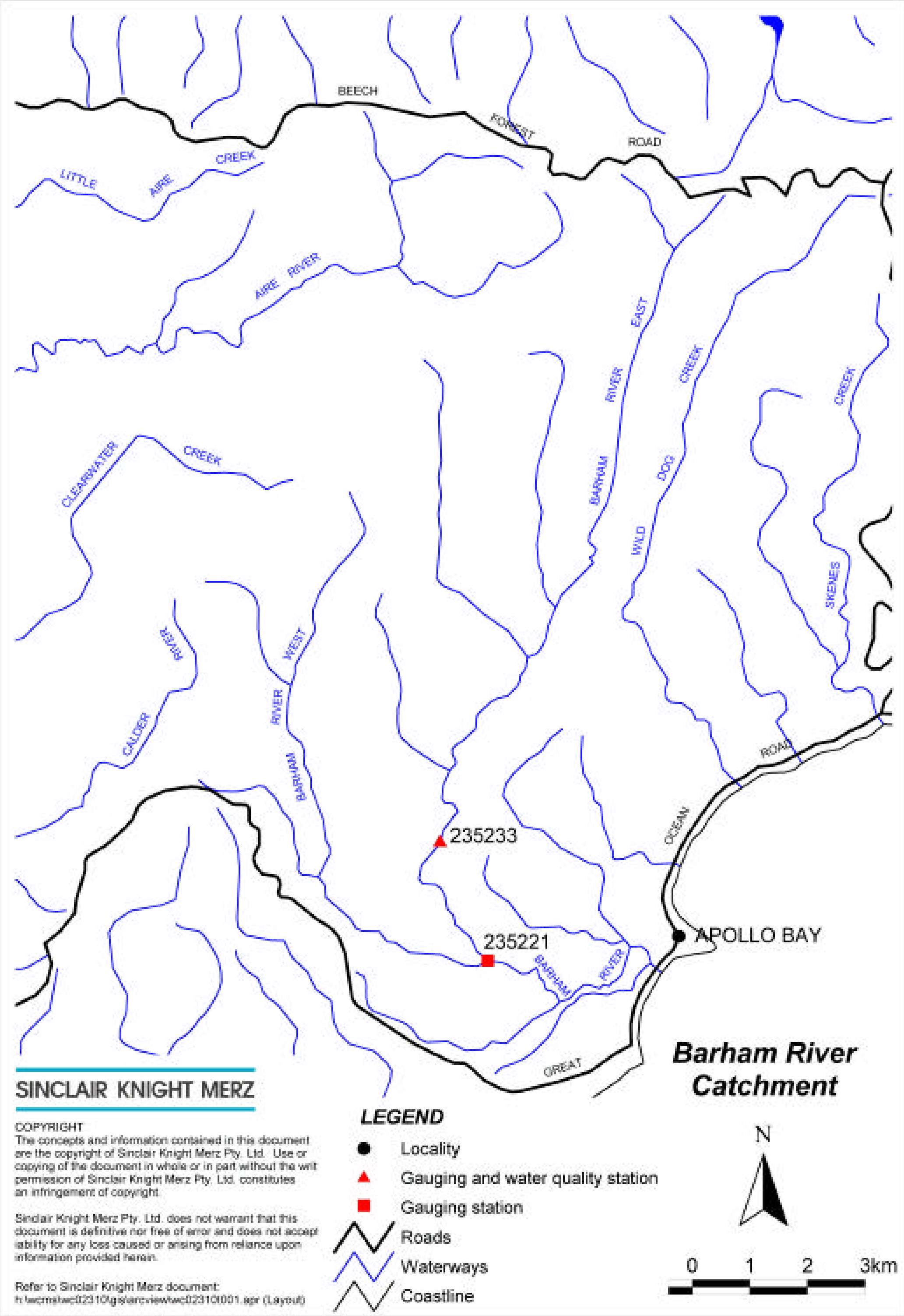
The East Branch and West Branch meander through cleared steep hilly areas before joining to flow across a short floodplain for approximately 4 km before discharging into the bay (See Figure 2.2). The mouth of the Barham River is subject to deferral and closure by natural sand bar development (Corangamite Catchment Authority, 2002). Extensive drainage has been carried out in the estuarine section of the Barham River to keep nearby wetlands dry. Some of these artificial drains are currently unstable and are affected by bed and bank erosion (Corangamite Catchment Authority, 2002).

The catchment slopes are susceptible to landslides and rockfalls. The river is subject to high energy conditions at times of flood, particularly in the more confined sections of the river. The banks of the Barham River including parts of the West and East Branches are affected by bank erosion. This erosion may be a result from natural causes however it has been accelerated in places due to land clearing and uncontrolled stock access (Corangamite Catchment Authority, 2002). More severe erosion has been observed around Conns Lane Bridge (downstream of the confluence).

Water is diverted from the Barham River for the purpose of irrigation, domestic and stock. There are currently four licences for extraction on the Barham River. Water for Apollo Bay is currently harvested from the West Barham Catchment from the offtake weir on the West Branch (Barwon Water, 2001).

Thirty fish species have been recorded in the Barham River and surrounding tributaries including eleven native freshwater species. (SKM, 2003). Out of these, one species, the Australian grayling (*Prototroctes maraena)* is listed as vulnerable under the Victorian Flora and Fauna Guarantee Act 1988, nationally threatened under the Commonwealth Environment Protection Biodiversity Conservation Act and listed on the 2002 IUCN Red List of Threatened Species. A total of 42 threatened flora species have been recorded in the Barham River Catchment (SKM, 2003).

The potential environmental impact posed by the water harvesting is expected to be of concern downstream of (below the confluence of the West and East Branches). One site was selected for the Barham River FLOWS assessment. The site selected was below the temporary pumping station operated by Barwon Water and which is also the proposed permanent extraction point. The site refers to the study area and was selected as it is representative of the downstream reach. The site contained a variety of key habitats including wood debris, pools, riffles and runs.



■ **Figure 3-1 The Barham River Catchment**

4. Key issues

There are a variety of environmental values that present in the Barham River catchment. The current condition of the Barham River is summarised in Table 4.1 and the main issues are discussed in more detail below.

- **Table 4.1 Current condition of the Barham River**

River Section	Description
West Branch – Forested section	Forested stream. Water supply catchment for Apollo Bay.
West Branch – Downstream end of forested section to confluence with East Branch	Riparian zone largely forested except at downstream end of reach. Bank erosion due to natural meandering processes, willow and stock damage at downstream reach.
East Branch – Forested section	Forested stream.
East Branch – Downstream end of forested section to confluence with West Branch	Parts of the riparian zone are cleared and parts are heavily forested. Contains willows and other weeds. Bank erosion due to natural meandering processes and stock damage.
Barham River – Confluence of east and west branches to tidal limit.	Moderate bank erosion and slumping from natural processes, stock damage, riparian vegetation loss, suspected bed control lowering.
Barham River – Tidal limit to coast.	Estuary subject to periodic closure. Bank erosion due to riparian vegetation loss and uncontrolled stock access.

Water quality is generally of good condition with the exception of elevated nitrate concentrations. The factors contributing to high nutrient concentrations in the Barham River are likely to be the cleared surrounding land and the result of stock access. The clearing of land reduces the level of nutrients absorbed by vegetation as well as the use of fertilisers may also contribute to the waterways. Unrestricted stock access can also contribute nutrients directly to the waterway through defecation. In addition, erosion resulting from stock access and geomorphological processes contributes sediment directly to the water column. These sediments contain nutrients that are resuspended during this process.

The loss or degradation of riparian vegetation can have significant ecological consequences, not just through the loss of riparian species but also through the subsequent detrimental impacts on aquatic ecosystems. Riparian vegetation serves as filter for light, nutrients and sediment and is important for moderating instream water quality such as water temperature. This influences dynamics such as growth, egg hatching and larval development of fish and other aquatic fauna.

Riparian vegetation also performs a long list of important functions in the creation and maintenance of fish habitat. Riparian zones maintain channel form, stabilise banks and give rise to debris dams which results in the accumulation of silt upstream and scour pools on the downstream side. This feature is a major habitat for fish. Many aquatic dependent species have been recorded within the catchment including the Australian Grayling.

Bank instability is a key issue affecting the river in the lower sections of the East and West Branches and past the confluence. The presence of vertical, exposed banks as well as mass failures and slumping can contribute sediment to the waterway. Unrestricted stock access to the river has exacerbated this erosion problem and has had a significant impact on the current condition. In the lower sections, on both sides of the bank, the riparian vegetation has been almost completely destroyed, leaving a cover of pasture grasses and thin cover of weeds. Bank erosion can also increase the difficulty for vegetation to establish along the reach that acts to stabilise the bank as well as provide terrestrial and instream habitat through the deposition of material.

For these reasons, it may be necessary to promote measures such as stock exclusion and streamside vegetation rehabilitation within the catchment to protect and enhance water quality. This would require active co-operation between stakeholders and authorities such as Corangamite Catchment Management Authority to initiate integrated catchment management programs. This however should be conducted as a program separate to, and independent of, the assessment of environmental flows for the Barham system.

5. Objectives

This section outlines the environmental objectives that have been developed for the project area. Two types of environmental objectives are proposed: policy and strategy objectives (reflect national, state and regional objectives) and catchment objectives (focus on environmental water management). The environmental objectives relate to specific river reaches and are accompanied by target statements that outline the expected flow and/or ecological response.

5.1 Policy and strategy objectives

The environmental flow recommendations should be implemented within the context and not in conflict with the following plans, strategies and Acts.

National
- Council of Australian Governments Water Reform Agenda; and
- Environmental Protection and Biodiversity Conservation Act 1999.

State
- SEPP Waters of Victoria Objectives;
- River Health Strategy;
- Stressed Rivers Program;
- Flora and Fauna Guarantee Act;
- Water Act;
- Biodiversity Strategy for Victoria; and
- Environmental Conservation Council Act 1998.

Regional
- Corangamite Regional Catchment Strategy 1997;
- Draft Corangamite Waterway Health Strategy 2001;
- Corangamite Nutrient Management Plan 2000;
- Draft Corangamite Floodplain Management Strategy 2002; and
- Draft Corangamite Native Vegetation Plan 2000.

There are a series of regional plans and strategies that are relevant to the environmental flows study. The Regional Catchment Strategy and additional regional plans recommend a series of actions and works that are aimed at improving ecosystem health, although not limited to the aquatic ecosystem. These actions generally in concept and action support the philosophy and implementation of the environmental flow recommendations. Water quality, erosion control and nutrient levels are key issues within the Barham River catchment and although there are impacts on the flow regime the key actions to deal with these issues are through other actions beyond environmental flow recommendations. The implementation of the Water Quality Strategy, Floodplain Management Strategy and Nutrient Management Strategy are key to gain the full benefit of subsequent environmental flows.

5.2 Catchment objectives

At the catchment scale the overall objectives include the following. These objectives are overall specific to the Barham River system.

1) Provide an adequate environmental flow regime throughout the year that includes:
   - minimum environmental flows during low flow periods;

- appropriate flushing flows to manage nutrient and coliforms levels; and
- larger channel forming flows.

2) Maintain longitudinal connectivity by:
   - maintaining a flow through the system during all months and;
   - maintaining a flow over instream structures.

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

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

5) Maintain and enhance threatened flora and fauna directly dependent on the aquatic ecosystem, with particular emphasis on threatened species.

6) Ensure that links to other strategies are fostered to promote the benefits of environmental flows.

5.3 Environmental objectives

The process of setting environmental objectives involves first identifying the environmental assets, setting environmental objectives against these, and then identifying the flow objectives required to meet the environmental objectives. For the purpose of this process, environmental objectives were developed only for those ecological assets that have a clear dependence on some aspect of the flow regime. Environmental objectives were developed for:

- particular species and communities,
- habitats, and
- ecological processes.

Following the FLOWS methodology the direction of a particular objective is expressed as one of three main targets:

1) Maintain – keep the condition of the resource in it's current state;
2) Restore – move the condition of the resource back to natural conditions; and
3) Rehabilitate – move the condition of the resource to some improved state other than natural (usually less than natural).

The objectives were developed such that, if met, the flow could sustain an ecologically healthy river (see NRE, 2002a p. 29). Therefore objectives were developed to protect current conditions and environmental assets of special concern, such as threatened species, and to sustain the natural communities and processes that are essential for river health.

■ **Table 5.1 Flow objectives for the Barham River system.**

	Environmental Objective	Process Objectives	Relevant Flow Component	Timing of Flow Component
	Fish			
F1a	Restore self sustaining populations of Australian Grayling	Habitat	Low/Summer freshes/high flows	Varying throughout the year
F1b		Spawning Movement/ Larval transport	High flows/ Freshes	May/June
F1c		Spawning/egg deposition	Freshes	January to April
F2a	Maintain self sustaining populations of Tupong	Movement	Freshes/High Flows	Autumn and Winter
F2b		Habitat	Low flow	All year
F3a	Maintain self sustaining populations of Flat-headed Gudgeon	Habitat	Low/Summer freshes	All year
F3b		Recruitment	Freshes	Winter/Spring
F4a	Maintain self sustaining populations of Australian Smelt	Habitat	Low/Summer freshes	All year
F4b		Recruitment	Freshes	Winter/Spring
F5a	Maintain self sustaining populations of Broad finned-galaxias	Habitat	Low/Summer freshes	All year
F5b		Spawning	Low/Freshes	Autumn/Winter
F5c		Recruitment	Freshes	Winter/Spring
F6a	Maintain self sustaining populations of Common galaxias	Habitat	Low/Summer freshes	All year
F6b		Spawning	Low/Freshes	Autumn/Winter
F7c		Recruitment	Freshes	Winter/Spring
F8a	Maintain self-sustaining populations of Spotted galaxias	Habitat	Low	All year
F8b		Spawning – in the lower reaches during low flows	Low	Winter/Spring
F9a	Maintain self sustaining populations of Short-finned Eel	Habitat	Low/Summer freshes	All year
F9b		Movement	High flow	Summer/Spring
F10a	Maintain self sustaining populations of Short-headed Lamprey	Spawning	Freshes	August to October
F10b		Habitat	Low flows/High flows	All year
	Vegetation			
V1a	Rehabilitate riparian vegetation community diversity and composition	Wetting	Low flow	All year
	Macroinvertebrates			
M1a	Rehabilitate benthic community diversity	Habitat	Low flow	Summer
M1b		Disturbances	Freshes	All year
	Water Quality			
W1a	Maintain acceptable water quality in pools	Habitat	Low flow	Summer
W1b		Mixing	Freshes	All year
	Habitat			
H1a	Restore instream habitat condition	Disturbance	Low flow	Summer
H1b		Sediment movement	High flow	Winter

5.3.1 Fish objectives

Seven environmental objectives specific to the fish species found in the project area have been developed (Table 5.1). These objectives are aimed at maintaining, and where necessary restoring, populations of native freshwater fish recorded from the river.

These objectives will be achieved by providing flows that will assist in the maintenance of a wetted stream during the summer flow period, and freshes during the spring that will assist in triggering spawning. High flows during winter/spring will assist in triggering migration through the system for selected species. Continuous flows will assist in the maintenance of longitudinal connectivity from the freshwater section of the river to the estuarine environment to allow for migration of the larvae, juveniles and adults of diadromous fish species.

5.3.2 Vegetation objectives

One objective has been developed to rehabilitate the vegetation communities of the Barham River (Table 5.1). The rehabilitation of these species endeavours to maintain the native vegetation in the upper catchment and restore a group of native vegetation in the project area. Once established, some species will be maintained by remaining wetted during periods of low flow, while the remaining species will be maintained by overbank flows. However, because the extraction of water from the system under the current level of water resource development is unlikely to impact on the frequency and duration of these events overbank flows will not be recommended.

5.3.3 Macroinvertebrate objectives

One environmental objective has been developed to rehabilitate macroinvertebrate community diversity within the project area (Table 5.1). This objective will be achieved by providing a range of flows. Low flows in summer maintain suitable habitat for the survival of macroinvertebrate species as they wet additional habitats and provide some ecological stress by drying out portions of the channel. In addition freshes will be important to wet areas of riffles and create a diversity of habitats. The low flow in winter will create a range of flow conditions, facilitate drift and move sediments to free interstitial spaces for habitat.

5.3.4 Water quality objectives

One objective has been developed that is aimed at maintaining acceptable water quality within the system (Table 5.1). This objective is achieved through the provision of both low and high flows. High flows, freshes and flushes lead to improvements in water quality as these flows mix pools and therefore reduce the likelihood stratification. Low flows also flush pools and assist in maintaining and regulating temperature and dissolved oxygen levels.

5.3.5 Physical objectives

One objective has been developed to restore the instream habitat condition of the Barham River system (Table 5.1). This is achieved through providing low and high flows. Low flows, particularly during summer, lead to disturbance of the exposed riverbed and banks and facilitate decomposition and processing of organic matter that contributes nutrients and carbon on re-wetting. In addition, high flows can transport sediment and organic matter downstream and also lead to desilting of gravel, or coarser substrate.

6. Flow components

The Draft Environmental Flows Technical Resource Manual (NRE, 2002a) describes the various components of a natural flow regime including periods of cease to flow, low flows, freshes during cease to flow/low flow periods, freshes during high flow periods, high flows, and flow variability. These are summarised below.

Natural flow in a river, in the context of flow management planning, refers to the flows that would exist if no diversion or storage of water occurred, but accepting that there have been in flows due to vegetation removal.

The magnitude, duration, frequency and timing of flows are key aspects of a natural flow regime to maintain channel form and viable populations of freshwater biota. Alteration of the natural flow regime of Australian rivers has been shown to interfere with the biology and assemblage structures of aquatic flora and fauna (Gehrke *et al.*, 1995) as well as alter natural geomorphic processes such as erosion and sedimentation (Benn and Erskine, 1994; Brooks and Brierley, 1997; Burston and Good, 1996; Prosser *et al.*, in press).

The flow components presented for each site may vary depending on the natural patterns of streamflows that historically passed through that site. The ecological, geomorphological and physicochemical significance of each of the hydrological regime components that must be maintained through the recommendations are outlined below.

An individual flow component is described by a spell. Each spell or event was distinguished from another for this study by a fourteen-day event independence ie. the spell must be separated from another spell by a minimum of 14 days. If the duration of time between spells was less, then the flow was considered to be one spell. The reporting of the duration of all spells is on the basis of the time period that they occurred naturally, while the frequency of such spells is based on how frequently they occurred naturally.

A flow regime was determined that aims to maintain and where possible restore the environmental values the Barham River catchment using a multi-disciplinary approach and integrated information on the ecology, hydrology, geomorphology and water quality.

The key components of the natural flow regime and the magnitude, duration, frequency and timing of these components have been derived from modelled natural flow regimes. These components are considered critical for biological, geomorphological and physicochemical processes:

1) periods of cease to flow;
2) low flows;
3) freshes during cease to flow/low flow periods;
4) freshes during high flow periods;
5) high flows; and
6) flow variability.

This section describes the flow components that have been identified as having significance to the project area with reference to ecology, hydrology, geomorphology and water quality. Although overbank flows may occur at a selection of sites within the catchment, the extraction of water under the current level of water resource development in the upper catchment is unlikely to impact on the frequency and duration of these due to the magnitude of the such events. In addition, these overbank flows can not be regulated by existing infrastructure as they occur outside of the stream channel, therefore there is no means of managing a flow of such magnitude. Subsequently, these components will not be discussed in any detail in this, or latter sections.

6.1 Cease to flow

The cease to flow is the period of no discernible flow in a river, or in practice when there is no measurable flow at a stream gauge, representative of the relevant reach. This may lead to either total or partial drying of the river channel, depending on the evaporation rate, groundwater exchange, depth of pools and the duration of cease to flow.

Cessation of flow is a common natural occurrence in Australian streams and there are a range of ecological functions provided by this flow component (Boulton *et al.*, 2000; Poff and Ward, 1989). During these periods, the river may contract to a series of isolated pools that are important refugia for recolonisers upon the return of flow. The biota in these pools are likely to be subject to intensified predation and physicochemical stresses (e.g. low dissolved oxygen concentrations). Periods of cease to flow often result in short term localised extinction of certain species (Puckridge *et al.*, 2000) with long term changes in diversity and biomass (Humphries and Lake, 2000; Puckridge *et al.*, 2000). Stream communities are relatively mobile (Allan, 1975; Boulton and Lloyd, 1991; Townsend and Hildrew, 1976) and will most likely have the ability to recolonise these habitats following the restoration of flow, as long as there are effective refuges (Jowett and Duncan, 1990). Drying of habitats and organic matter facilitates the decomposition and processing of organic matter and following rewetting this then provides a fresh pool of nutrient and carbon inputs for the system (Baldwin and Mitchell, 2000; Nielsen and Chick, 1997).

Overall there is a significant ecological benefit from this component. The risks are in the removal or extension of the duration of this component or addition of the component in a system in which it did not naturally occur. The cease to flow period is a period of stress for the ecosystem and extension of the duration of this period can have deleterious effects on the ecosystem.

For this study, cease to flow periods have not been included as only naturally occur 2 percent of the time under natural flow conditions at the gauging station on the West Branch (SKM, 2003). As the site selected for the FLOWS assessment is downstream of the West and East branches, it unlikely that there are any cease to flow periods as stream flow at the East branch is always above 1 ML/d.

6.2 Low flow

The low flows may be described as the flow that generally provides a continuous flow through the channel within the representative reach. The flow may be limited to a narrow area of the channel, but will provide flow connectivity between habitats within the channel. In some systems a low flow may inundate a range of habitats and be more than just a pool connecting flow. There are two key benefits of a low flow; either in the maintenance of a flow during the period when flow is generally limited, or through the temporary exposure of channel habitat normally inundated at higher flows.

During summer periods the low flow may be a critical flow, sustaining the habitats in stress through an overall lack of flow. Low flows are critical to sustain flow stressed streams and link habitats in rivers in times of limited flow. Restoration of low flows have been used to ameliorate poor water quality and sustain suitable aquatic habitat (Mitchell *et al.*, 1996). Low flows also provide important channel inundation for the maintenance of aquatic and riparian vegetation (Arthington *et al.*, 2000).

Biota requires periods of slow flowing water for a range of functions. Low flows have been suggested as important for recruitment of some native fish in lowland rivers (Humphries *et al.*, 1999). As high flows often drown out riffle or other shallow habitats, low flows are critical in the maintenance of these habitats and the resulting habitat diversity for biota (Arthington *et al.*, 2000).

6.3 Freshes

A fresh is the term that is used to denote small and short duration peak flow events in excess of the median natural flow for that period. These are flows that exceed the baseflow and last for at least several days, often as a result of intensive, and sometimes localised, rainfall. They are distinct from persistent long-term changes in the seasonal baseflow or large high flow and flood events.

Freshes are generally characteristic of either summer or spring. Summer freshes are usually a result of short peak summer rain events and often are brief flows in periods of very low or no flow over summer. Summer freshes are particularly important in rivers for the maintenance or improvement of water quality, as the short periods of high flow mixes pools and allows an input of fresh water.

Freshes are a key component of the variability of flow regimes providing short pulses in flow and the short temporal scale variability that is identified as a key component of natural flow regimes for a range of ecosystem factors (Hughes and James, 1989; Jowett and Duncan, 1990; Poff and Allan, 1995; Poff and Ward, 1989; Puckridge *et al.*, 1998).

The expert panel of the Sustainable Diversions Limits Project for the Department of Natural Resources and Environment stated that flow above the median natural daily discharge for a period of 5 days or more was a surrogate for events of ecological importance over winter (NRE, 2002b). The freshes have been described in a way that has consistency with the indices used in the Sustainable Diversions Limits Project. The duration of a fresh will be dependent on the ecological process that is linked to that fresh, and there is no consistent duration that can be applied for all seasons.

6.4 High flows (in channel)

This flow component encompasses a broad range of flows. The key characters that distinguish this flow component from freshes or other large flows are the persistent increases in the seasonal baseflow that remain within the channel. These flows occur during winter and are those which cover the bed of the stream and some of the lowest in-channel benches may be flooded, creating further habitat. High flows do not fill the channel to bankfull and are unlikely to provide substantial channel forming forces. High flows effectively wet and connect most habitats within the main channel. Specific discharges have been linked as a requirement for breeding by some fish species (Koehn and O'Connor, 1990; O'Connor and Koehn, 1998) and can act as triggers for breeding for other species (Harris and Gehrke, 1997; Humphries, 1995; Koehn and O'Connor, 1990). High flows are important to provide a period of connectivity for fish migration through a system.

6.5 Flow variability

Maintaining natural variability in stream discharge throughout the year is important for both ecological and geomorphological processes. Under natural conditions variations in water surface level and associated wetting and drying regimes of stream banks are important for the creation of channel forms (e.g. pools, riffles, bars, benches) and habitat attributes (e.g. large woody debris transport and placement). However, constant flows and water surface levels tend to accelerate the rate of scour at the bank toe which, in turn, may lead to bank slumping. Furthermore, constant discharge may have some deleterious effects on life history strategies and subsequent recruitment of native fish, macrophyte and macroinvertebrate species.

7. Recommendations

This section describes the identified environmental flows requirements for the Barham River system. The analysis has been undertaken separately for the high and low flow periods. In the Barham River, the low flow period occurs between December and May and high flows occur between June and November.

These flow recommendations have been developed based on the long term flows expected at the specific site. While natural inter-annual variation will result in the recommendations not being achieved in some years, they will be over achieved in other years. Hence, the aim is to achieve the recommendations in the long term.

Flows in this section are often described as either flow duration plots or flow percentiles. These are two forms of presenting a similar representation of the flow regime. For example, the 90% flow is the flow exceeded 90% of the time and is generally a low flow. Conversely, the 10% flow is the flow exceeded 10% of the time and is a high flow event. These can also be read from the flow duration plots.

The following section details the recommended environmental flows (Table 7-1) and rationale for the Barham River at the long term future extraction site. Four flow recommendations have been developed for this River. The range of flows recommended includes a minimum summer and winter flow and summer and winter freshes.

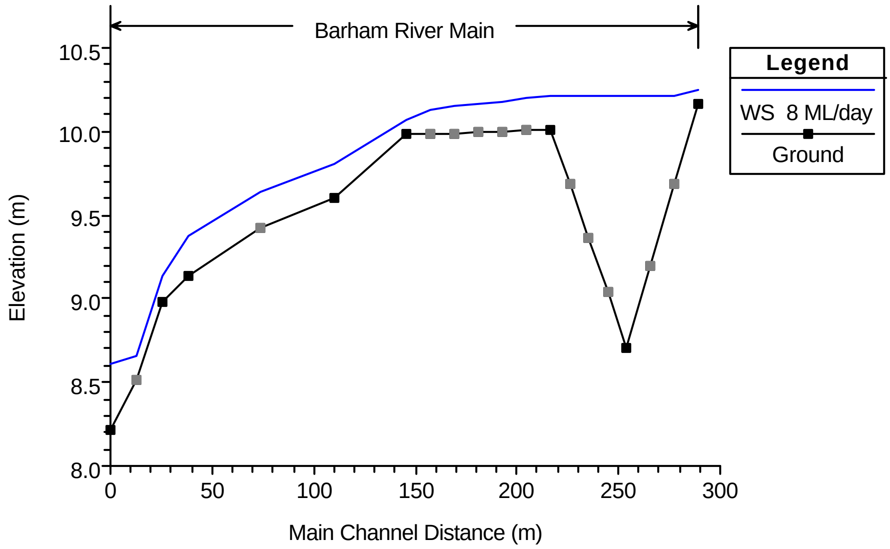
■ Table 7-1 Environmental flow recommendations for Barham River at the long term future extraction site

Environmental water requirements (EWR)					Rationale				
EWR	**Season**	**Magnitude**	**Frequency**	**Duration**	**Fish**	**Vegetation**	**Macroinvertebrates**	**Water quality**	**Habitat**
1.1	Summer (Nov-Apr)	Minimum 8 ML/day	Annual	All year	F1a, F2b, F3a, F4a, F5a, F6A, F7b	V1a	M1a	W1a	H1a
1.2		>14 ML/day	3 annually	10 days	F1a, F1b, F2a, F2b, F3a, F3b, F4a, F4b, F5a, F5b, F5c, F6a, F6b, F7a, F7b		M1b	W1b	
1.3	Winter (May-Oct)	Minimum 35 ML/day	Annual	May – Oct	F1a, F1b, F2a, F6b, F7b		M1b	W1b	H1b
1.4		>69 ML/day	3 annually	7 days	F1b, F2a, F3b, F4b, F5b, F5c, F6b, F7b		M1b	W1b	
1.5		>770 ML/day	Annual	1 day (minimum)					

7.1.1 EWR 1.1 – Summer low

The recommended low summer flow is 8 ML/d. This flow corresponds to the 67th percentile summer flow naturally and is equivalent to 6.6. ML/day at the East Branch. A discharge of this magnitude provides low flow over the shallows between isolated pools. Overall the low flow objectives are to maintain a minimum habitat for a range of biota through summer. In the Barham River this includes a number of native fish species. To maintain the community diversity a range of habitats must be provided, including deep water in the pools and habitat in the margins a refuge for smaller individuals. The recommended flow provides a limited connection between the pools (Figure 7-1), although it is unlikely that this flow would allow free movement by fish between the pools. This flow maintains a wetted region in the riffle areas, for example at cross sections 1 and 6 the wetted width is 3.27 m and 3.50 m respectively. Maintenance of this riffle habitat is a critical objective for the macroinvertebrate community diversity.

The flow between the pools provides a low level of input to the pools that will maintain water quality within the important pool habitats. This would particularly assist in maintaining temperature and dissolved oxygen within an appropriate range. In addition, the improvements to water quality would also assist in diluting of nutrient concentrations within the pools. The improvements to water quality would subsequently improve aquatic habitat for fish, macroinvertebrate and vegetation species.



■ **Figure 7-1 Long profile of the Barham River site, showing the water level at the recommended summer low flow of 8 ML/day.**

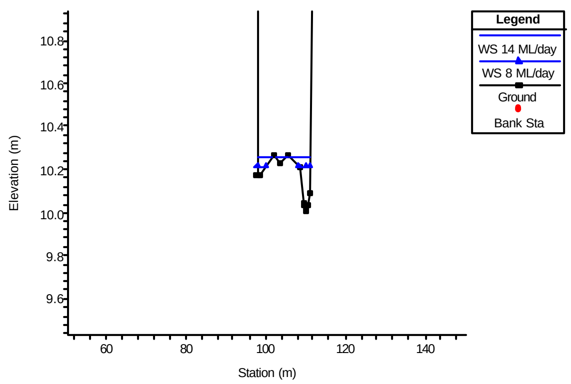
7.1.2 EWR 1.2 – Summer freshes

A recommendation for the summer fresh is for three freshes of 14 ML/day, with a minimum duration of 10 days. This flow is equivalent to a flow of 10 ML/day in the East Branch. The summer fresh will inundate the shallow bars as illustrated in cross section 5 (Figure 7-2). The increased water level will move organic matter and promote primary and secondary production. The summer freshes provide a significant flow between the pools with an increased depth through the shallow flow controls (Figure 7-3). This increased flow will have water quality benefits and also provide habitat diversity in riffles and pool margins.

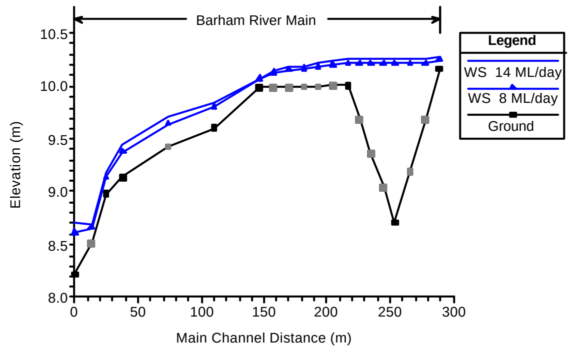
The freshes are aimed at improving water quality in the remnant pools, particularly targeting high temperatures and low dissolved oxygen that would occur in these pools over summer. In addition, the freshes would also assist in reducing nutrients and coliforms in the pools by dilution.

Australian grayling need periods of increased flow in summer to induce movement and leading to spawning. These summer freshes will provide both the cue and the connectivity for this purpose. This element is critical to achieve the aim of restoring Australian grayling to this reach.

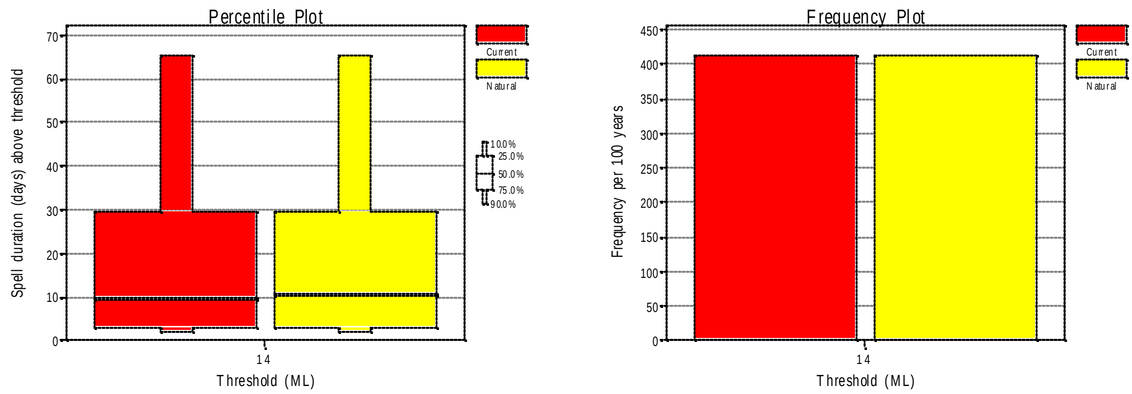
The recommended duration of the summer freshes is 10 days, this duration is equivalent to the natural median duration (Figure 7-4). This duration will provide long enough for the additional areas to be fully wetted and allow significant inputs of fresh water into the pools. The recommended frequency is 3 times per year, which is slightly less than the natural frequency of effectively 4 times per year (Figure 7-4). The summer freshes do not act as cues for spawning or significant movement, although multiple events are required so that there are not long periods of only the low flows without the variability from the freshes.



■ **Figure 7-2 Cross section 5 at the Barham River showing the water level at 8 ML/day and 14 ML/day.**



■ **Figure 7-3 Long profile of the Barham River site, showing the water level at the 8 ML/day and 14 ML/day.**

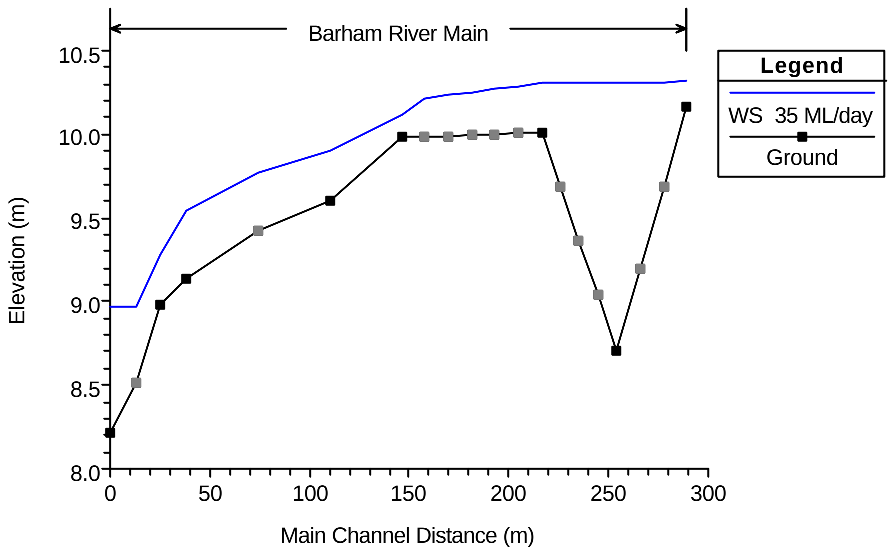


■ **Figure 7-4 Spell duration (left) and frequency (right) of summer freshes in the Barham River greater than 14 ML/d under current and natural conditions.**

7.1.3 EWR 1.3 – Winter low flow

The winter low flow recommended for the Barham River is 35 ML/d, which is equivalent to 24 ML/day at the East branch. The functions of the winter low flow are to provide connectivity through the system, wet all of the key habitats in the reach and provide a range of shallow and deep habitats. The recommended flow of 35 ML/day provides a significant depth throughout the reach as shown on the long profile (Figure 7-5).

These flows will maintain a permanent connectivity between pools to allow fish species to move freely upstream and downstream. This movement is critical to allow the pre-spawning migration and dispersal of adult fish where required. A large proportion of the native freshwater fish found in the Barham River are diadromous species, including the common galaxias, spotted galaxias and the broad finned galaxias. Consequently, the longitudinal connectivity through the winter spring period is critical for these species. The higher flows also provide a diversity of habitats, which are inportant refuges for juvenile fish species following recruitment. This low flow is important to inundate the stream margins as these are areas in which spotted galaxias spawn, hence the flow is critical for successful recruitment.



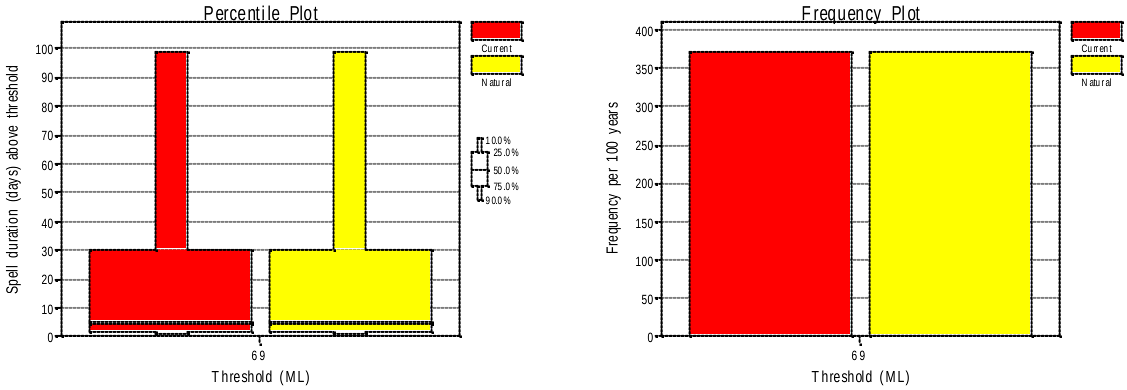
■ **Figure 7-5 Long profile of the Barham River site, showing the water level at the recommended winter low flow of 35 ML/day.**

7.1.4 EWR 1.4 – Winter freshes

Winter freshes have also been identified for the Barham River. Three freshes during the winter flow period, with a magnitude of 69 ML/d (47 ML/day in the East Branch) and lasting for 7 days each are recommended (Figure 7-6).

Spring and late winter freshes are considered critical elements in the spawning of many species of native freshwater fish, including species found in the Barham River (such as many of the galaxias species). There is little definitive evidence as to whether the freshes are cues for movement or spawning or other processes, although there is a link with overall successful recruitment.

Flows of this magnitude will also improve water quality within pools due to the additional freshwater inputs and subsequent mixing. Benthic community diversity would also benefit, similarly to low flow periods. The disturbance posed by this fresh will lead to a temporary reduction in species abundance and distribution, while on subsidence of flows a greater species diversity will inhabit the stream.

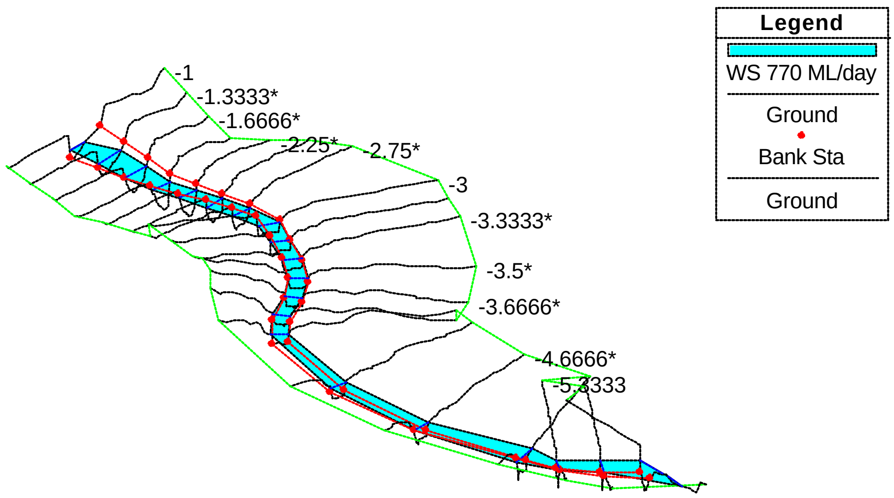


- **Figure 7-6 Spell analysis of Barham River. Duration (left) and frequency (right) of flow spells in the Barham River greater than ML/d under current and natural conditions.**

7.1.5 EWR 1.5 – Winter high flow

The recommendation for the winter high flow is a short duration (less than 2 days) flow of 770 ML/day (600 ML/day in the East Branch). This flow is retained within the channel (Figure 7-7) and consequently would cause no damage to fixed infrastructure. The recommended flow is in the order of the natural annual high flow.

The winter high flow needs to be an annual event to maintain the ongoing channel forming processes. The beds and banks of the Barham River, particularly further downstream, are relatively mobile. An annual large flow will serve to maintain habitat diversity by transporting sediment that has accumulated, moving sand and changing mobile habitat features.



- **Figure 7-7 The Barham River site in plan view showing the water level (blue) at 770 ML/day.**

7.2 Supporting recommendations

1. Monitor the implementation of the recommendations and adapt where appropriate

Environmental flow recommendations are made based on the current issues and values of an aquatic system. It is important that the environmental flow recommendations are monitored to assess their effectiveness and modify the recommendations as necessary. It is important to monitor the implementation of the environmental flow regime for the Barham River and adapt the recommendations where necessary to account for any alterations in system issues and values. General water quality parameters such as dissolved oxygen and nutrients should also be monitored at key sites within the catchment.

2. Fencing and stock control of stream length and revegetation

The major issue in the reach selected is the lack of riparian vegetation and bank stability. Both banks have been extensively cleared in the study reach. Unrestricted stock access will prevent future regeneration of riparian species. Livestock trample and eat seedlings, contribute nutrients, through excrement, to the water, and amplify erosion through their movement within the area. Due to the current lack of fencing along the Barham River, stock can freely pass into the sensitive riparian zone and river channel. It is recommended that the riparian zones of this area be fenced to encourage regeneration. Sections of the bank are already exposed, particularly where stock have access. The banks at this site are vulnerable to erosion under high flow conditions. Any further reduction in vegetation cover may contribute to increased bank erosion through this reach.

The revegetation program would require active co-operation between stakeholders and authorities such as Corangamite Catchment Management Authority to initiate integrated catchment management programs. This however should be conducted as a program separate to, and independent of, the assessment of environmental flows for the Barham system.

3. Continue water quality monitoring program

Water quality monitoring within the Barham River is currently limited to routine monitoring by the Victorian Water quality Monitoring Network. Barwon Water conducted an additional water quality monitoring program at the long term future extraction site and 200m upstream of the confluence of both the east and west branches.

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