Environmental flow assessment for the Birches Creek catchment

FLOW RECOMMENDATIONS

- Final
- October 2005

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Contents

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Ron Cosgrove	Community
Andrea Joyce	Department of Sustainability and Environment (Regional)
Tim Kelly	Environment Victoria
Jock Lieshman	Loddon/Campase Dryland Implementation Committee
John McKinnon	Irrigator
Joy Sloane	Department of Primary Industries
Bob Wilson	Community

Abbreviations used in this report

BE	Bulk Water Entitlement
EFTP	Environmental Flows Technical Panel, also referred to as the Scientific Panel
G-MW	Goulburn-Murray Water
LWD	Large woody debris (instream wood)
MU	Management Unit
MSOMP	Major Storages Operating Monitoring Program
SKM	Sinclair Knight Merz
SSI	Seasonally weighted score
VRHS	Victorian River Health Strategy
VWQMN	Victorian Water Quality Monitoring Network

1. Introduction

A bulk water entitlement (BE) process is scheduled to commence in the Birches Creek catchment. The process aims to convert the poorly-defined access rights to water of existing users to the well-defined bulk entitlements that set the basis for a legal, regulated water market. As part of informing the process, the North Central Catchment Management Authority requires an environmental flow assessment of the Birches Creek catchment.

The study area for the assessment was Birches Creek downstream of Newlyn Reservoir to the junction of Creswick Creek, and Tullaroop Creek downstream of the Creswick Creek confluence to Tullaroop Reservoir.

Environmental flow recommendations were determined using the framework of the standardised statewide method for determining environmental water requirements in Victoria, referred to as the FLOWS method (DNRE, 2002).

This *Final Recommendations* paper is the last output in the method and presents the environmental flow recommendations. It was preceded by the *Issues Paper*, which summarises all the supporting information required to develop the environmental flow recommendations and should be read in conjunction with this report.

1.1 Report structure

Section 2 provides a summary of the methods employed to develop flow recommendations for Birches and Tullaroop Creeks downstream of Newlyn Reservoir. A summary of the updated list of environmental flow objectives for the study area is presented in Section 3. The flow recommendations for each reach are presented in Section 4 along with a brief assessment of the current degree of compliance.

2. Methods

The FLOWS method was used to determine recommendations for Birches Creek downstream of Newlyn Reservoir to the junction of Creswick Creek, and for Tullaroop Creek downstream of the Creswick Creek confluence to Tullaroop Reservoir. A brief description of the method applied to this study area is provided below. The full method and rationale is presented in DNRE (2002).

2.1 Reach and site selection

The first stage of this project was to collect and collate all available information relating to the study area so as to describe the biodiversity, ecological processes, hydrology and operation of the system. This information was used to identify key reaches and sites. Based on a delineation of physical and biological characteristics and water management the study area was divided into four reaches (Table 2-1).

A site visit was conducted to select a site that was representative of the key features within each reach. These representative sites were used in the detailed analysis to assist in quantifying environmental flow recommendations (Table 2-1). The methods and outputs of this task are described in the *Site Paper*, which is included as an appendix to the *Issues Paper* (SKM, 2005a).

Table 2-1 Reaches and field assessment sites.

Reach		Representative site
1	Newlyn Reservoir to the confluence with Hepburn Race	End of Victoria Road, 'Omaru' property
2	Hepburn Race to Lawrence weir	Floodway between Beaconsfield and Daylesford Clunes Rd.
3	Lawrence weir to the confluence with Creswick Creek	Nelsons Bridge, Smeaton Road
4	Creswick Creek confluence to Tullaroop Reservoir	Unamed Road off Clunes Mt.Cameron Road

2.2 Field assessment

A rapid field assessment of the representative sites was conducted by the EFTP (Environmental Flows Technical Panel). The EFTP for this project comprised Kylie Swingler (macroinvertebrates and water quality), Tim Doeg (macroinvertebrates), Dr Bruce Abernethy (geomorphology) and Dr Simon Treadwell (fish).

At each site the EFTP undertook a series of standard descriptive tasks. Six or seven transects were identified and marked with pegs for subsequent surveying. The number of transects was sufficient to develop a hydraulic model at the site and represent a range of channel and habitat features of the site, such as hydraulic control points (e.g. logs, riffles), pools (zones of deeper slow-flowing water) and channel benches.

Once selected, photographs were taken of each transect and a sketch drawn to identify important geomorphic and ecological features. An evaluation of the key components of the flow regime was carried out to identify flows that would be structurally or ecologically important for the creek system.

2.3 Environmental flow objectives

Environmental flow objectives were developed for those ecological assets that have a clear dependence on some aspect of the flow regime, such as:

- individual species and communities;
- habitats; and
- ecological (physical and biological) processes.

Environmental flow objectives for Birches Creek were endorsed by the Steering Committee and Consultative Panel. They are provided in the *Issues Paper* (SKM, 2005a) and summarised in Section 3.

2.4 Survey of selected reaches

Transects identified by the EFTP were surveyed and incorporated into a hydraulic model for each site. Transect survey points focussed on the channel detail, with fewer points out of the main channel.

2.5 Hydraulic model

A one-dimensional hydraulic model of each site was prepared to develop a relationship between flow, water depth and velocity using the one dimensional steady state backwater analysis model HEC-RAS. This software calculates water surface profiles and other flow characteristics using a series of surveyed transects and estimated roughness factors.

Roughness factors and other flow control features such as riffles, log weirs, and rock or weed obstructions were noted at each transect. Water surface levels were surveyed for each transect which together with estimates of streamflow from nearby gauges allowed for accurate calibration of the models.

For each model, survey data was used to create interpolated cross sections, allowing the model to represent features such as riffles and log weirs that occurred between the surveyed cross sections. These weir and riffle features were usually controlling water levels in the stream, therefore their representation in the model was crucial.

The cross sections, roughnesses, and riffle details were adjusted so that the modelled water levels matched the surveyed water levels. To represent other flows, hydraulic boundary conditions were developed by assuming the energy grade slope at the upstream and downstream ends of the calibrated model were consistent for all flows.

Sensitivity checks were undertaken for the adopted roughness factors because these were based on site observation, and hence likely to be very approximate. These sensitivity checks showed that roughness factors had little effect on flow characteristics and water levels. This is because each site consisted predominantly of short, steep riffles and deep, slow moving pools.

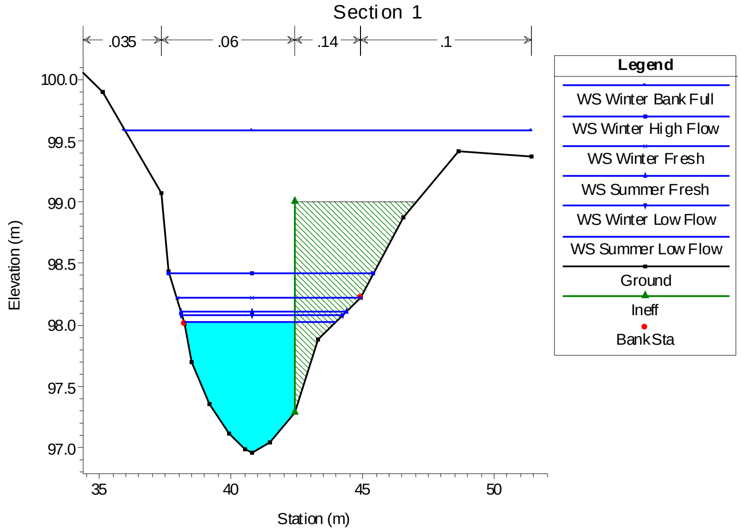
In the case of the riffles, the roughness may affect the depth of flow across the riffle by a few centimetres, but the overall level of the riffle itself (ie. the top level of the log / rock ledge compared to the normal stream bed) has a much greater impact on stream water levels. Therefore the roughness factors adopted for riffles do not have a significant impact on water levels.

Also, roughness factors can only affect water levels where there is significant flow velocity. In deep pools, the velocity is typically very low, often below 0.1 m/s. In these conditions, roughness factors do not significantly affect water levels.

Hydraulic output

A key output from the hydraulic model is a graphical representation of each transect. An example of a hydraulic output is provided in Figure 2-1. The green line ("ground" in the legend) represents the ground surface, reflecting the channel shape at the transect. Small black squares on the ground line show the exact points where survey measurements were taken (note that these are more frequent within the channel than further out). Horizontal blue lines within the cross section represent the water surface at the various flows (which are detailed in the legend). The green hatching represents vegetation in the channel that prevents flow in that area.

The outputs from the model include the flows (ultimately expressed in ML/d) required to cover the steam bed to a certain depth, or inundate channel features such as benches.



- **Figure 2-1 Example transect output from the hydraulic model in Reach 3 at different flows.**

2.6 Hydrology

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

Hydrological assessment involved consideration of a range of hydrological parameters to describe the flow regime, including:

- flow duration curves which show the percentage of time that a flow of a given rate is exceeded;
- time series graphs to examine the sequence of flow events, particularly during very dry or very wet conditions; and
- flow spell analysis using GetSpells to describe the frequency, duration and start month of flow spells (flow events above or below a flow magnitude that serves a specific function – See Section 3).

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GetSpells output

GetSpells software is used to describe and compare the duration, start months and frequency of flow events (spells) that rise above or fall below a stipulated flow threshold under current and natural conditions. These analyses are carried out using modelled daily flow data for either the high flow (winter/spring) or low flow (summer/autumn) periods but not the entire year combined. For our analyses, flow spells are independent of each other if separated by more than seven days. It is important to note that for low flows, spells that fall *below* the threshold are evaluated. For freshes, high and bankfull flows, spells *above* the threshold are evaluated.

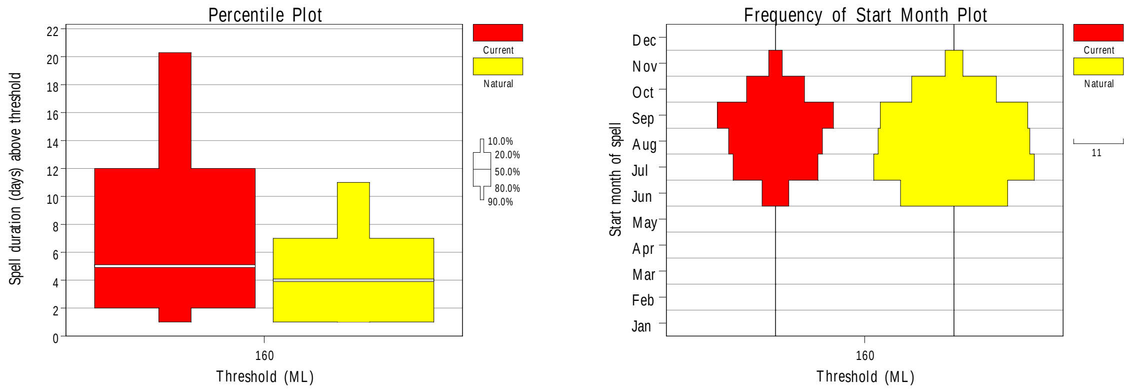
An example of a GetSpells output is provided in Figure 2-2 using a threshold value of 160 ML/d. The **percentile plot** summarises the duration of flow spells over 160 ML/d. In the plot the median spell duration (50th percentile) is indicated with variation in spell durations described by the box and whiskers plots. Sixty percent of flow spells have a duration that lies within the box (20th and 80th percentiles) while 80 percent of the spells are described by the whiskers (spells within the 10th and 90th percentiles). In the example provided in Figure 2-2 for spells higher than 160 ML/d that occurred during winter/spring under current conditions:

- the median duration of spells above the threshold is 5 days;
- 60% of spells above the threshold lasted between 2 and 12 days; and
- 80% of spells above the threshold lasted between 2 and 20 days.

The upper box and whisker plot have a greater spread than the lower box and whisker. This indicates that the data is skewed, that is to say that spells of a long duration occur relatively less frequently than shorter spells.

The **frequency of start month plot** describes the frequency distribution of the months that flow spells have started in. In Figure 2-2 high flows during the winter/spring period most often start during September under current conditions.

The frequency of spells is determined by the median (50th percentile) number of times that spells over 160 ML/d occur in the modelled flow data. No plot is produced for this result.



- **Figure 2-2 Duration (left) and start month (right) of flows above 160 ML/d during winter/spring under current and natural conditions for Reach 1.**

2.7 Development of recommendations

Environmental flow recommendations for Birches Creek were determined by the EFTP at a workshop on 7 July 2005. The EFTP worked through the process of determining flow recommendations on a reach by reach basis.

For each reach the basic ecological condition was discussed and previously determined environmental flow objectives were summarised and reviewed. Photos and field notes taken during the field assessment were examined along with transects from the hydraulic model in order to identify key environmental features (i.e. benches, riffles).

Within each reach, each flow component was considered in turn. If a particular flow component could be associated with an environmental flow objective for the reach, a flow recommendation was made. The criteria for each flow component were considered (e.g. flow that provides a depth of 0.1 m at the shallowest riffle) and equated to a volume using the hydraulic model (Table 2-2). Spells analysis was conducted on this volume to determine the natural frequency and duration of that flow.

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Table 2-2 Criteria used in determining environmental flow recommendations for each flow component.

Flow component	Physical description	Criteria for determining recommendation
Low flow	Minimum flow that provides a continuous flow throughout the channel (maintains permanent pools with an adequate depth of water to provide habitat for aquatic biota)	The EFTP used a depth of 0.1 m at the shallowest cross section for macroinvertebrates and a depth of 0.4 m depth in the shallowest pool for the largest fish species (i.e. River Blackfish) (see *Issues Paper*).
Freshes	Small and short duration peak flow events that exceeded baseflow	The EFTP used the inundation of in -channel low flow benches, and availability of fish passage in the shallowest cross-section as morphological features. The inundation of benches will move organic material and redistribute food around the stream.
		The EFTP used an average velocity of 0.4 m/s to scour biofilms (Biggs *et al.*, 1999).
High flows	Persistent increases in the seasonal baseflow that remain within the channel	The EFTP used an increase in habitat area (compared to freshes) and the inundation of in-channel benches and high flow channels as morphological features.
Bankfull flow	Completely fill the channel	Morphologically defined, with some interpretation required as transects may differ in capacity.

2.8 Ramp rates

The rate at which flows rise and fall are known as ramp rates. These rates are environmentally significant for short duration spells such as freshes and bankfull flows. If rates of rise are too fast they may exceed the ability of biota to adapt, thereby causing stress. Rapid falls in flow can increase the risk of bank failure leading to increased erosion and sediment loads, or stranding of biota in rapidly exposed habitat areas.

Ramp rates were calculated from daily modelled natural data for each reach. The differences between flows on individual days were divided into days when flows rose and days when flows fell. The ratio of the change in flow was calculated for each rise or fall. The maximum desirable rate of rise was selected as the 90th percentile value of all recorded rates of rise (representing a fairly high rate that was recorded naturally) and the maximum desirable rate of fall was selected as the 10th percentile value of all recorded rates of fall.

The ramp rate recommendations are provided as a percentage of the previous days' flow. For example a recommended rate of rise of 336% stipulates that flow on a given day should not exceed 336% of the previous day's flow (Table 2-3).

Table 2-3 Recommended maximum rates of rise and fall (expressed as a percentage of the previous days flow).

Reach		Rate of rise	Rate of fall
1	Newlyn Reservoir to the confluence with Hepburn Race	337%	59%
2	Hepburn Race to Lawrence weir	332%	60%
4	Lawrence weir to the confluence with Creswick Creek	328%	60%
4	Creswick Creek confluence to Tullaroop Reservoir	322%	60%

2.9 Compliance with recommendations

Compliance of flow recommendations to the current flow regime was determined for each recommended flow component. Compliance was based on the percentage of time that a given flow volume, frequency and duration was exceeded and is described below.

2.9.1 Volume compliance

For summer and winter low flow volumes compliance is based on the percentage of time (days) within the relevant period that the flow exceeds the volume recommendation. For all other flow components (fresh, high, bankfull and overbank) the volume compliance is based on the percentage of years when the volume recommendation is met. For example, a 70% compliance with the volume recommendation for a fresh or high flow means that in 70% of years the volume recommendation was met or exceeded in the defined season.

2.9.2 Frequency compliance

Compliance with the frequency or number of events is based on the percentage of years when the recommended number of events was met. For example, if one event is required each year but currently only occurs in eight years out of ten then compliance is 80%. If two events are recommended to occur each year but currently two events only occur every second year then compliance is 50%.

Note, that for the purposes of testing compliance, frequency has been determined based on the percentage of years when the threshold was exceeded, rather than an average of the number of exceedences in a 100 year period.

2.9.3 Duration compliance

Compliance with duration is based on the percentage of events (i.e. when the volume is met at the right time of year) where the recommended duration is met. For example, the recommended event duration may be seven days but if only 25% of events last for seven days or longer then compliance is 25%. Compliance has been colour coded according to the arbitrary ranges in Table 2.4.

- **Table 2.4 Key to colour coding for percentage compliance.**

Component	Mostly complies	Frequently complies	Often complies	Occasionally complies	Rarely complies	Never complies
Volume (ML/d) as percentage of years (or time in the case of low flows) when recommended volume is met	>95% of years	76-95% of years	51-75% of years	26-50% of years	5-25% of years	<5% of years
Frequency (no. of events per year) as percentage of years when frequency is met	>95% of years	76-95% of years	51-75% of years	26-50% of years	5-25% of years	<5% of years
Duration (days) as percentage of events when duration is met	>95% of events	76-95% of events	51-75% of events	26-50% of events	5-25% of events	<5% of events

2.9.4 Flow comparisons

The FLOWS method is based on the determination of flow components to meet agreed environmental objectives. As such, in regulated rivers the recommended flow does not necessarily resemble the natural flow regime; rather it resembles a regime that is considered by the EFTP to be one that maximises the ability to achieve the stated environmental objectives. For comparative purposes and to assist in the BE process, flow recommendations have been compared with the current and natural flow regime. This comparison has been undertaken on the proviso that the flow statistics used are only surrogates and is not meant to imply ideal or preferred flow; they are for comparative purposes only.

Volume comparison

There are no universally defined percentiles that correspond to specific flow components. However, as simple surrogates, for the current and natural flow regimes, the volume of each flow component has been estimated where the low flow equivalent has been calculated as the 80th percentile of the daily flow, freshes have been calculated as the 50th percentile of the daily flow and high flows as the 20th percentile of the daily flow in the specified period. The low flow is typically considered as the flow that occurs on more than 80-90% of days and the high flow is typically considered as the flow that occurs on less than 5-20% of days (Poff *et al.*, 1997). We have chosen the 80th percentile to represent low flows and the 20th percentile to represent high flows simply for comparative purposes. There is no standard percentile definition for a fresh flow, however the FLOWS method described a flow that exceeds the median flow (50th percentile) for more than five days as a fresh (DNRE, 2002).

As an example, to compare the summer low flow between the current and natural flow regimes the 80th percentile of flow in the summer period has been calculated for both regimes and can be compared to highlight the differences in the low flow volume between natural and current. This volume can then be compared with the recommended low flow volume.

Frequency and duration comparison

For frequency and duration, the comparison between current and natural is based on the median number (50th percentile) of events in the specified period and the median (50th percentile) duration of each event.

The following table is an example of how to interpret the compliance summary tables for each reach.

The summer fresh recommendation is 15 ML/d, four times year and for three days duration. For comparative purposes the current summer high flow (20th percentile) is 4 ML/d and the natural summer high flow (20th percentile) was 10 MLd. Under the current regime the volume recommendation is met 70% of the time.

The current median frequency is one event each year and the recommended frequency is only met in 5% of years. The current median duration is three days and the recommended duration of three days is met for 50% of events.

The summer low flow recommendation is 5 ML/d. For comparative purposes the current summer low flow (80th percentile) is 3 ML/d and the natural summer low flow (80th percentile) was also 3 ML/d. Under both the current and natural regime the low flow recommendation is complied with 38% of the time.

Flow recommendations			Percentage of years (vol and no.) or events (dur.) when flow recs. are complied with for the current flow regime	Differences between each flow component for the current and natural flow regime for comparative purposes	
Component	**Flow recommendation**			**Current equivalent**	**Natural equivalent**
Summer/autumn (December – May)					
Summer low	**Volume**	5	38	3	3
Summer fresh	**Volume**	15	70	4	10
	Frequency	4	5	1	4
	Duration	3	50	3	8
Winter/spring (June – November)					
Winter low	**Volume**	10	99	8	21
Winter fresh	**Volume**	55	90	36	61
	Frequency	3	15	2	3
	Duration	5	60	13	6

The winter low flow recommendation is 10 ML/d. The current winter low flow (80th percentile) is 8 ML/d and the natural winter low flow (80th percentile) was 21 ML/d. Under current conditions the recommendation is complied with 99% of the time.

The winter fresh recommendation is 55 ML/d on three occasions for five days duration. Under current conditions the winter fresh (50th percentile) is 36 ML/d and the natural fresh (50th percentile) was 61 ML/d. Under current conditions the volume recommendation is met in 90% of years. However, the frequency recommendation is only met in 15% of years.

Under natural conditions the median number of events greater than 55 ML/d was three. The current median duration is 13 days and only 60% of events last for at least five days. Under natural conditions the median duration of an event greater than 55 ML/d was six days.

3. Environmental flow objectives

Environmental flow objectives set the direction and target for the environmental flow recommendations and are clear statements of what outcomes should be achieved in providing environmental flows.

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

- individual species and communities;
- habitats; and
- ecological (physical and biological) processes.

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

1) maintain – keep the condition of the asset in it's current state;
2) restore – move the condition of the asset back to natural conditions; and
3) rehabilitate – move the condition of the asset to some improved state (but different to natural).

The environmental flow objectives for Birches Creek are summarised in Table 3-1. No specific geomorphological objectives have been developed for Birches Creek as geomorphological issues are mainly associated with impacts from willow invasion, continued stock access, mining sources and degradation of the riparian zone, which are not manageable with flow manipulation. Similarly, no environmental objectives have been developed for water quality in Birches Creek as the EFTP does not believe that environmental flows should be recommended to ameliorate poor water quality, when it can be reduced at the source (i.e through appropriate landuse practices).

For each environmental objective there are one or more functions. These functions focus on more specific aspects of objectives that can be managed for through the flow objectives. For example the environmental objective for maintaining the native fish community depends on providing flow for survival (maintain habitat) and a flow that provides localised movement between habitats. The functions provide an important link between the environmental objectives and the components of the flow regime.

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Table 3-1 Environmental flow objectives for Birches Creek.

Asset	Objective	No.	Function	Flow component	Timing
REACH 1					
Macroinvertebrates	Restore or maintain macroinvertebrate community to comply with SEPP objectives for AUSRIVAS, SIGNAL and number of families	M1-1	Maintain habitat, including access to riffles (water depth > 10 cm)	Low flow	Summer
					Winter
		M1-2	Flush sediment from riffles and pools	Freshes	Throughout the year
		M1-3	Entrain organic matter from the riparian zone	High	Spring
Fish	Maintain native fish community composition and abundance, including River Blackfish and Mountain Galaxias	F1-1	Maintain habitat	Low flow	Summer
					Winter
		F1-2	Allow localised movement between pools (water depth > 40 cm)	Freshes	Throughout the year
Instream and riparian flora	Rehabilitate current complexity and diversity of instream vegetation	V1-1	Maintain water depth	Low flow	Summer
					Winter
		V1-2	Disturbance	Freshes	Throughout the year
	Rehabilitate riparian vegetation extent, structure and composition	V1-3	Drying	Low flow	Summer
		V1-4	Maintenance	Freshes	Throughout the year
		V1-5	Inundate banks to favour flood tolerant species	High	Spring
REACH 2					
Macroinvertebrates	Maintain current macroinvertebrate community to comply with SEPP objectives for AUSRIVAS and number of families	M2-1	Maintain habitat, including access to riffles (water depth > 10 cm)	Low flow	Summer
					Winter
		M2-2	Flush sediment from riffles and pools	Freshes	Throughout the year
	Restore current macroinvertebrate community to comply with SEPP objectives for SIGNAL	M2-3	Entrain organic matter from the riparian zone	High	Spring
Fish	Maintain native fish community composition and abundance, including River Blackfish and Mountain Galaxias	F2-1	Maintain habitat	Low flow	Summer
					Winter
		F2-2	Allow localised movement between pools (water depth > 40 cm)	Freshes	Throughout the year
Instream and riparian flora	Maintain current complexity and diversity of instream vegetation	V2-1	Maintain water depth	Low flow	Summer
					Winter
		V2-2	Disturbance	Freshes	Throughout the year
	Rehabilitate riparian vegetation extent, structure and composition	V2-3	Drying	Low flow	Summer
		V2-4	Maintenance	Freshes	Throughout the year
		V2-5	Inundate banks to favour flood tolerant species	Freshes	Spring

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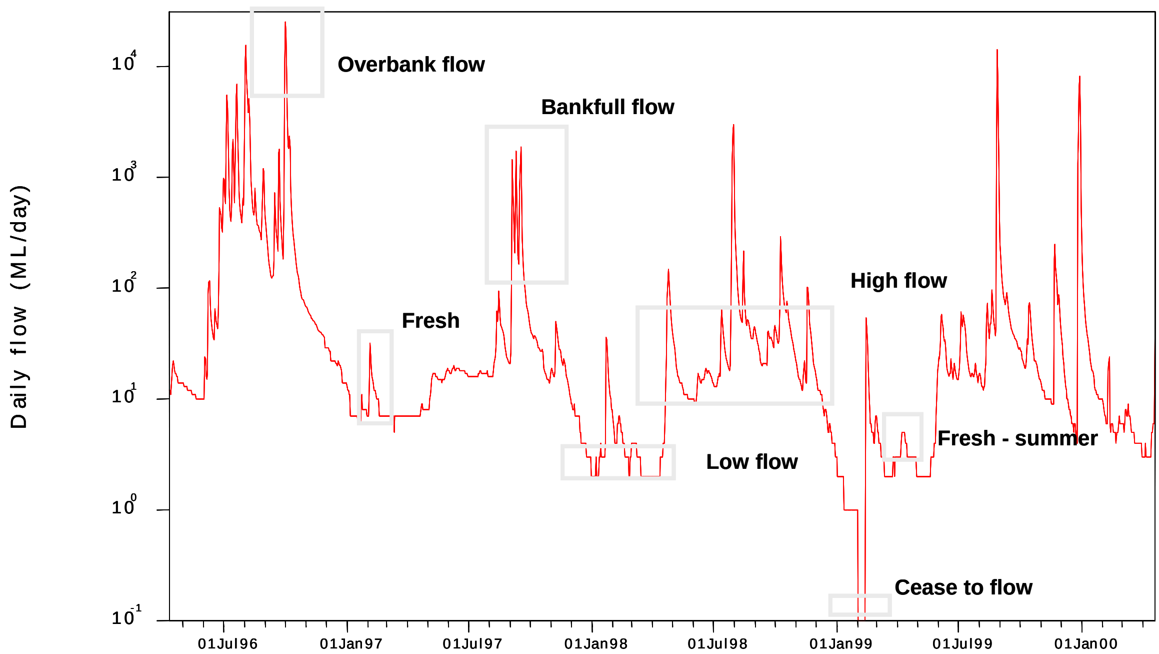
Table 3-2 Environmental flow objectives for Birches Creek cont'd.

Asset	Objective	No.	Function	Flow component	Timing
REACH 3					
Macroinvertebrates	Maintain current macroinvertebrate community to comply with SEPP objectives for AUSRIVAS, and number of families	M3-1	Maintain habitat, including access to riffles (water depth > 10 cm)	Low flow	Summer
					Winter
		M3-2	Flush sediment from riffles and pools	Freshes	Throughout the year
	Restore current macroinvertebrate community to comply with SEPP objectives for SIGNAL	M3-3	Entrain organic matter from the riparian zone	High	Spring
Fish	Maintain native fish community composition and abundance, including River Blackfish and Mountain Galaxias	F3-1	Maintain habitat	Low flow	Summer
					Winter
		F3-2	Allow localised movement between pools (water depth > 40 cm)	Freshes	Throughout the year
Instream and riparian flora	Maintain current complexity and diversity of instream vegetation	V3-1	Maintain water depth	Low flow	Summer
					Winter
		V3-2	Disturbance	Freshes	Throughout the year
	Maintain current riparian vegetation extent, structure and composition	V3-3	Drying	Low flow	Summer
		V3-4	Maintenance	Freshes	Throughout the year
		V3-5	Inundate banks to favour flood tolerant species	High	Spring
REACH 4					
Macroinvertebrates	Restore or maintain macroinvertebrate community to comply with SEPP objectives for AUSRIVAS, SIGNAL and number of macroinvertebrate families	M4-1	Maintain habitat, including access to riffles (water depth > 10 cm)	Low flow	Summer
					Winter
		M4-2	Flush sediment from riffles and pools	Freshes	Throughout the year
		M4-3	Entrain organic matter from the riparian zone	Bankfull	Spring
Fish	Maintain native fish community composition and abundance, including River Blackfish and Mountain Galaxias	F4-1	Maintain habitat	Low flow	Summer
					Winter
		F4-2	Allow localised movement between pools (water depth > 40 cm)	Freshes	Throughout the year
Instream and riparian flora	Rehabilitate current complexity and diversity of instream vegetation	V4-1	Maintain water depth	Low flow	Summer
					Winter
		V4-2	Disturbance	Freshes	Throughout the year
	Rehabilitate riparian vegetation extent, structure and composition	V4-3	Drying	Low flow	Summer
		V4-4	Maintenance	Freshes	Throughout the year
		V4-5	Inundate banks to favour flood tolerant species	Freshes	Spring

Functions can be met through one of more flow components that constitute a typical flow regime (Figure 3-1). Flow components are elements of a flow regime that have specific environmental effect (DNRE, 2002). Six flow components are used in this assessment of Birches Creek and these are listed in Table 3-3. The key environmental functions of each of the flow components are described in the sections below and are summarised in Table 3-3.



- **Figure 3-1 Typical daily flow series.**

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Table 3-3 Environmental functions of different flow components in Birches Creek.

Flow component	Function
Summer/autumn (December-May)	
Low flow	▪ disturb lower channel features including riffles by exposing and drying. ▪ allow accumulation and drying of organic matter in the dry areas of the channel such as benches. ▪ maintain permanent pools with an adequate depth of water to provide habitat for aquatic biota. ▪ maintain adequate depth of water flow over riffles.
Freshes	▪ provide flow variability to maintain species diversity of emergent and marginal aquatic vegetation and to drive zonation patterns across the channel. ▪ maintain emergent and marginal aquatic vegetation by wetting lower channel banks and benches. ▪ improve water quality by flushing and turning over any stratified pools. ▪ temporary increase in longitudinal connectivity between pools to allow greater movement of macroinvertebrates and fish.
Winter/spring (June – November)	
Low flow	▪ sustained longitudinal connectivity for movement of the macroinvertebrates and fish. ▪ sustained inundation of riffles and lower benches to maintain habitat for emergent and marginal aquatic vegetation. ▪ cause die back of terrestrial vegetation that has encroached down the bank during the low flow period. ▪ increase habitat area for instream flora and fauna including large woody debris and overhanging banks.
Freshes	▪ entrain terrestrial organic matter that has accumulated on benches. ▪ Provide some limited sediment transport (sediment entrainment and deposition with no, or limited, net change in channel form). ▪ Provide flow variability to maintain species diversity of emergent and marginal aquatic vegetation and to drive zonation patterns on the banks.
High	▪ entrain terrestrial organic matter that has accumulated on benches (at higher level than freshes). ▪ provide sediment transport (sediment entrainment and deposition with no, or limited, net change in channel form). ▪ provide flow variability to maintain species diversity of emergent and marginal aquatic vegetation and to drive zonation patterns higher on the banks. ▪ increase amount of habitat available (compared to freshes).
Bankfull	▪ Disturbance and resetting of aquatic and riparian vegetation communities. ▪ transport of organic matter that has accumulated in the upper channel. ▪ removal of aquatic and riparian vegetation through scouring. ▪ promote regeneration of River Red Gum.

3.1 Summer/autumn

Low flow

Summer/autumn low flow refers to the minimum flow remaining in the channel (either after diversions are taken out, or water released from reservoirs). The objective of this flow in Birches Creek is to maintain water in permanent pools and wetted areas over riffles.

The minimum water level intends to preserve the wetted riffle areas as refuges for macroinvertebrates and provide adequate depth in pool refuges for fish. Maintaining flows over the riffles and connectivity between pools will also help slow the deterioration of water quality that occurs in pools during low flow periods.

Freshes

Summer/autumn freshes refer to the short increases in flow in the channel due to localised rainfall events. This variation in water levels is important for maintaining species diversity in the emergent and marginal aquatic vegetation communities and is the principal driver of zonation at the channel margins. This is because different species have varying degrees of tolerance to the timing and duration of inundation. Another function of the freshes will be to wet low-lying channel zones such as riffles and benches, thereby helping relieve drought-stress on emergent and marginal vegetation that has become exposed during the low flow period. Fish and other aquatic fauna will become more able to move between pool habitats during freshes because of increased depth across riffles areas. The brief increase in flow will also help to improve water quality by flushing and mixing any pools that have begun to stagnate and become stratified, in particular during prolonged periods of low and/or zero flow. Freshes can also serve to desilt riffle areas, thereby improving habitat for macroinvertebrates that use these habitats.

3.2 Winter/spring

Low flow

Winter/spring low flows refer to the minimum flow in the channel during the high flow period. The objective of this flow in Birches Creek is to provide conditions of sustained water levels and inundate lower channel portions such as benches and islands.

Prolonged inundation of the lower channel portions will drown encroaching terrestrial vegetation while maintaining habitat for emergent and marginal vegetation during the spring growth season. Encroaching terrestrial vegetation can over-grow water tolerant native species and prevent their establishment. There will also be a general increase in habitat availability for aquatic biota as large woody debris, branch-piles and riverbanks become inundated and available for colonisation. Habitat diversity will also increase as higher flows create a greater diversity of flow velocity habitats. This may be particularly important for macroinvertebrate community diversity, which can contain species specialised for high velocity habitats.

Freshes

Winter/spring freshes are short duration increases in flow that occur during the high flow period between June and November. Similar to the summer/autumn freshes, the winter/spring freshes will provide flow variability important for maintaining diverse aquatic vegetation along the edges of the river. Freshes will entrain organic matter that has accumulated in the terrestrial channel sections, and to a lesser degree transport sediment. Entrainment and deposition of sediment is unlikely to result in a net change in channel form during these flow events. High flow freshes may negatively impact on aquatic vegetation by scouring the channel bed, however this is a natural process.

High

Winter high flows are seasonal increases in flow that fill the channel to a deeper extent than winter freshes. They effectively wet and connect most habitats within the main channel and provide lateral connectivity between the main channel, high-flow channel and benches. Maintaining occasional inundation of these habitats provides significant carbon returns to the stream after a period of significant production (e.g. plants, algae and macroinvertebrates) and provides connectivity for fish to move between habitats.

Bankfull

Bankfull flow refers to a flood flow that fills a large proportion of the river channel without escape onto the floodplain. A bankfull flow acts as a significant disturbance to the geomorphology and ecology of the river. These large flows can reform the channel by scouring banks and transporting sediment. Ecological succession will be reset in both aquatic and riparian communities as plants and animals are swept downstream or drowned. Organic matter that has accumulated in the higher portions of the channel will be entrained and transported downstream. Included in the organic material will be large woody debris that becomes dislodged and caught up the lower channel sections.

4. Environmental flow recommendations

This section outlines the environmental flow recommendations for each reach. A standard format is provided for each reach and includes:

- a summary of the current condition. These are a very brief summary of the geomorphology, macroinvertebrates, fish and vegetation condition taken from information presented in the *Issues Paper*.
- flow recommendations. A rationale of the various flows chosen for recommendation. A number of transect plots from HEC-RAS are presented with the flow recommendations that demonstrates where each flow would be expected to occur in the channel transect.
- current compliance with recommendations. An analysis of the current frequency and duration of the recommended flows was undertaken to indicate where the recommendations are being achieved by current operational practices.
- supporting recommendations. These indicate non-flow related issues that require attention in order that the flow recommendations will achieve their intended objectives.

An ‘or natural’ proviso has been added to the flow recommendations. This proviso allows for natural variability in the flow regime and is applicable to the low flow magnitude, and the frequency and duration of freshes, high flows and bankfull flows. The proviso requires that the recommendations need to be measured against the natural flow frequency and duration that would have occurred without any diversions, defined as ‘natural’ in this study.

The addition of the ‘or natural’ proviso to the low flow recommendation means that cease to flows will occur at the natural frequency and duration. Cease to flows are an ecological disturbance that maintain a diverse macroinvertebrate and macrophyte community and dry habitats and substrates. If the natural flow (i.e. inflow to Newlyn Reservoir and/or Hepburn Lagoon) is lower than the recommended flow, then the natural inflow should be released rather than the minimum flow value. In this way, the flow variability, including cease to flow, is maintained in the natural state. Significantly, it means that water does not have to be released to top up flows to the minimum value if the natural flows are lower than this.

The addition of the ‘or natural’ proviso to freshes, high and bankfull flows means that these flows will occur at their natural frequency and duration. For example, if there is a recommendation for winter/spring freshes to exceed 40 ML/d, four times a year for a period of five days, this does not mean that flows over 40 ML/d need to occur four times every year, irrespective of natural flow conditions. If there are less than four natural flows greater than 40 ML/d in winter/spring in a particular year, then only the natural number of flows need to be present downstream for the frequency recommendation to be achieved. However, if there are more than four flow events that exceed 40 ML/d in a year, then only four of those need to be delivered to the downstream reach in order to meet the recommendation.

On the other hand, if in a year when four or more such natural flows occur, only three or less flows are passed, then it should be considered that the recommended flow has not been met.

Similarly, with the recommended duration. If a natural fresh greater than 40 ML/d occurs for less than five days, then the natural duration for that fresh needs to be met downstream. Any natural freshes with durations over five days however, can be truncated at five days (subject to suitable rates of fall) and the remainder of the fresh can be harvested.

4.1 Reach 1: Newlyn Reservoir to Hepburn Race

4.1.1 Current condition

The current condition of Reach 1 was detailed in the *Issues Paper*. A summary of the current condition is provided in Table 4-1.

Table 4-1 Current condition of Reach 1: Newlyn Reservoir to Hepburn Race.

Aspect	Current condition
Hydrology	▪ Mean annual flow has been reduced by about 26% ▪ Mid-level and very low flows have been most impacted
Geomorphology	▪ Streamform is profoundly influenced by the invasion of willows ▪ The channel has divided in parts due to thick willow root mats
Water quality	▪ Birches Creek downstream of Newlyn Reservoir may be affected by cold water releases
Fish	▪ Four native fish species have been recorded – River Blackfish, Mountain Galaxias, Flatheaded Gudgeon and Australian Smelt
Macroinvertebrates	▪ No macroinvertebrate data available but would expect fauna typical of slower flowing foothill streams
Instream and riparian flora	▪ Willow dominated riparian vegetation ▪ Bank species are terrestrialised

4.1.2 Flow recommendations

The environmental flow recommendations for Reach 1 are summarised in Table 4-2. No cease to flow recommendation has been made because the environmental benefit of such a flow in this reach is considered negligible, particularly given the degraded condition of the system and the relatively low natural frequency of cease to flow events.

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- **Table 4-2 Summary of flow recommendations for Reach 1: Newlyn Reservoir to Hepburn Race.**

Stream		Birches Creek		**Reach**	Newlyn Reservoir to Hepburn Race		
Compliance point		Confluence of Birches Creek and Hepburn Race		**Gauge No.**	No gauge present		
Season	**Component**	**Magnitude**	**Frequency**	**Duration**	**Rise**	**Fall**	**Objective**
Summer	Low flow	3 ML/d (or natural)	1 per year	6 months			M1-1, F1-1, V1-1, V1-3
	Freshes	10 ML/d	4 per year (or natural)	3 days	337%	59%	M1-2, F1-2, V1-2, V1-4
Winter	Low flow	10 ML/d (or natural)	1 per year	6 months			M1-1, F1-1, V1-1
	Freshes	40 ML/d	3 per year (or natural)	5 days	337%	59%	M1-2, F1-2, V1-2, V1-4
	High	160 ML/d	3 per year (or natural)	5 days	337%	59%	M1-3, V1-5

Summer/autumn: low flow

A low flow of 3 ML/d is recommended for Reach 1. This flow will maintain adequate habitat throughout the site to ensure the survival of aquatic biota. As there are few natural habitat features at this site, the criteria for determining the minimum habitat was to provide a minimum depth of 10 cm at the shallowest riffle (Transect six). Flows at this level will maintain deep pool habitat for fish and adequate water depth over the riffles for macroinvertebrates. It will also expose large areas of the streambed, which serves as an important function for nutrient processing by allowing terrestrial organic matter to accumulate on the exposed channel.

Outputs from the HEC-RAS model for Site 1 indicate that flow less than 3 ML/d does not provide a depth of 10 cm at Transect six and would severely reduce the capacity to maintain habitat for instream flora and fauna. A flow of 3 ML/d will maintain deep pools (1 m) and provide a depth of 11 cm at Transect six (Figure 4-1).

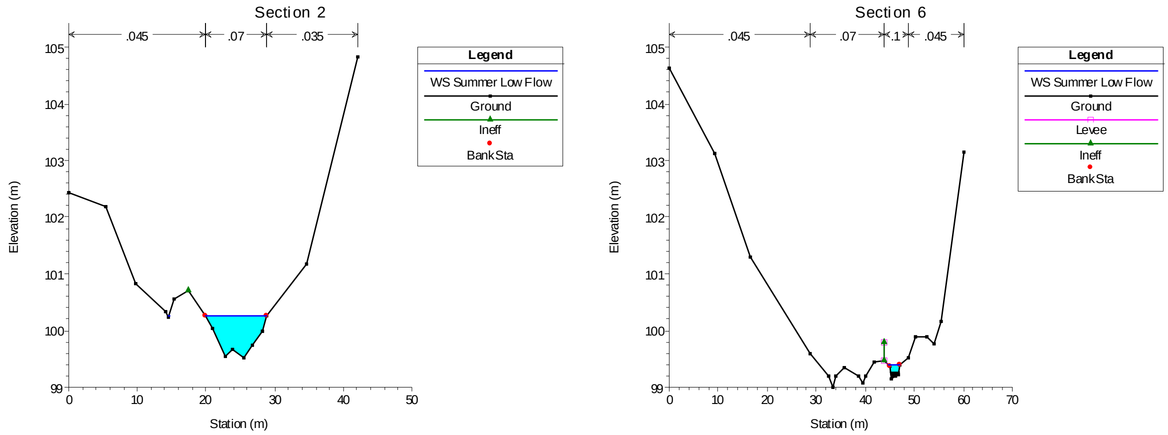

Figure 4-1 Stage height in pool (Transect 2, left) and riffle (Transect 6, right) transects at the recommended threshold for summer/autumn low flows at Site 1.

Under natural conditions, the flow in this reach of the stream would have fallen below the recommended low flow threshold three times a year for a median duration of 20 days (Figure 4-2). Under current conditions this drop occurs more frequently, median twice a year, but for a shorter length of time (Figure 4-2). It is recommended that the summer/autumn low flow be maintained at 3 ML/d (or natural) between December and May.

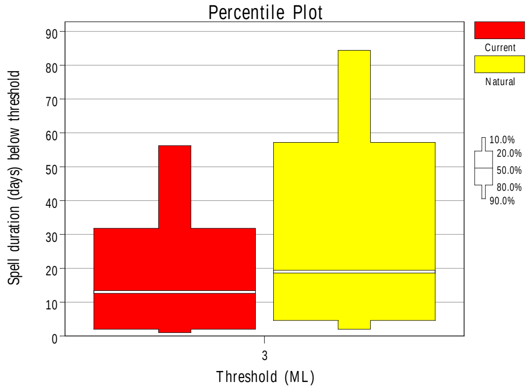

Figure 4-2 Duration of flows below 3 ML/d under current and natural conditions for Reach 1.

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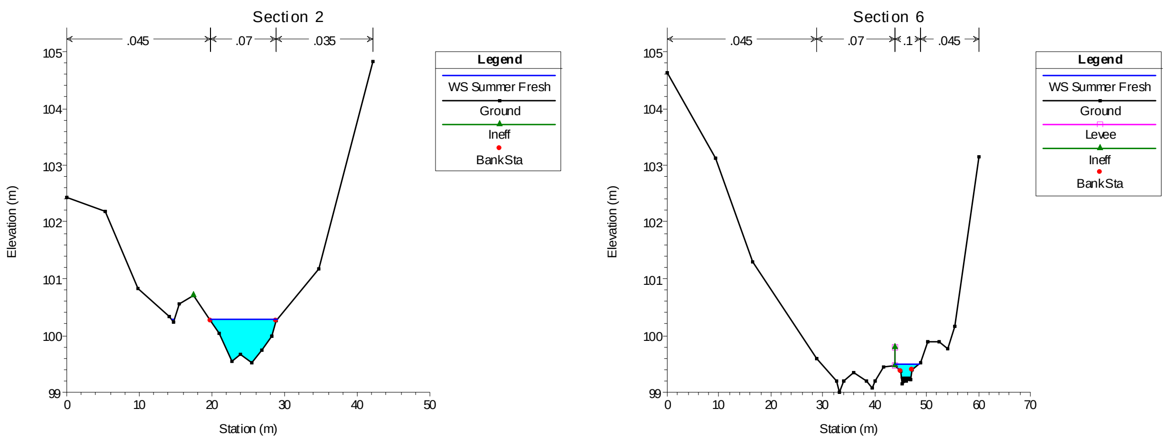
Summer/autumn: freshes

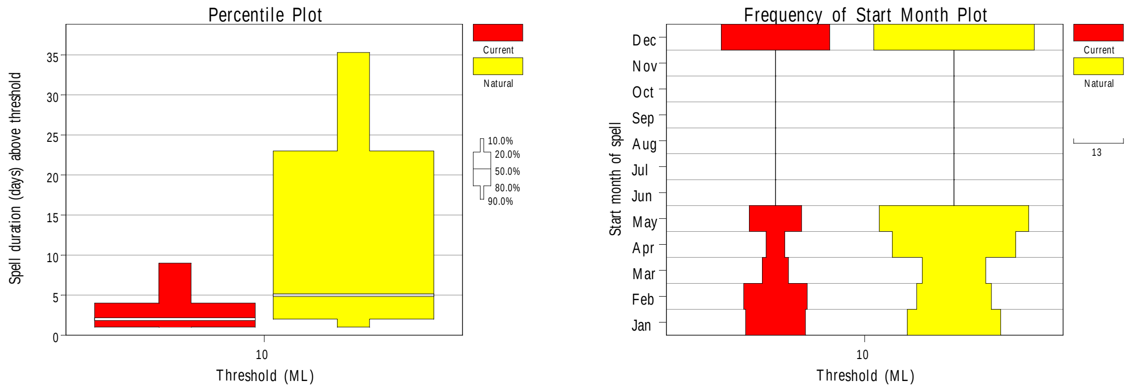
The recommended flow for providing a fresh during summer/autumn in Reach 1 is 10 ML/d. At this flow the wetted area of the channel begins to extend over the low lying channel areas. Outputs from the HEC-RAS model at Site 1 indicate that this flow will result in some lateral expansion of the riffle areas and raise water depths by about 10 cm (Figure 4-3). This increase in depth will temporarily enhance connectivity between pools, allowing some fish movement.

The recommended flow produces average water velocities between 0.07 and 0.16 m/s which should, according to Gordon *et al*. (1992), move particle sizes greater than 0.5 mm (i.e. fine to medium sand and silt) which may have accumulated on willow root mats or at the bottom of shallow pools. These velocities will also help improve water quality by flushing and turning over pools that may have been deteriorating in quality over the low flow period.



- **Figure 4-3 Stage height in pool (Transect 2, left) and riffle (Transect 6, right) transects at recommended threshold of summer/autumn low flows at Site 1.**

Under natural conditions, flows that exceeded the recommended threshold for summer/autumn freshes would have occurred four times a year and lasted for an average of five days during the low flow period (Figure 4-4). Under current conditions, flows exceeding this threshold occur less often, twice a year, and for a shorter duration (median two days). The start months of flow spells above the threshold tend to occur less frequently in April. It is recommended that low flow freshes be provided for minimum duration of three days and on four occasions per year during the low flow period in order to mimic natural conditions and coincide with natural increases in flow.

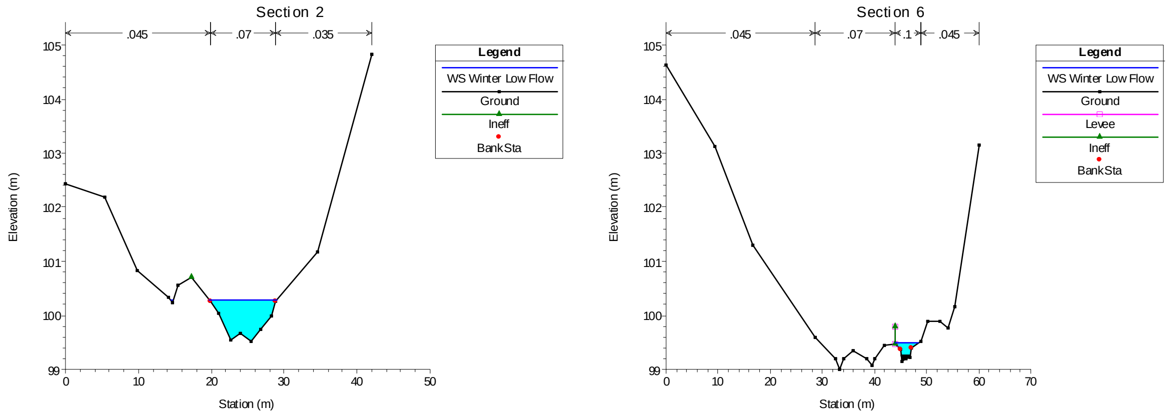


- **Figure 4-4 Duration (left) and start month (right) of flows above 10 ML/d for summer/autumn freshes under current and natural conditions for Reach 1.**

Winter/spring: low flow

A winter low flow of 10 ML/d is recommended for Reach 1. At this flow the wetted area of the smaller side channels and flow over riffles will be sustained (Figure 4-5). This sustained flow will suppress encroaching vegetation that has been able to colonise the lower channel zone during summer/autumn low flows while providing ideal conditions for aquatic vegetation, particularly in the spring when many species are entering their growing phase.

Outputs from the HEC-RAS model at Site 1 indicate that water depths across the site increase from the summer/autumn low flow level by around 5 cm (Figure 4-5). This increase in depth provides more habitat for fish and macroinvertebrates because more habitat features such as undercut banks are inundated compared to the summer/autumn low flow period. This flow will also entrain willow leaves from the smaller channels.



- **Figure 4-5 Stage height in pool (Transect 2, left) and riffle (Transect 6, right) transects at the recommended threshold of winter/spring low flows at Site 1.**

The level of inundation of flows higher than 10 ML/d were examined but were considered to provide relatively little additional benefit given the extra volume of water that are required. However, if the flow drops below this threshold the lower channel portions would not receive sustained wetting and the ecological benefit of the flow would be reduced.

Flow spells below 10 ML/d in winter are longer in duration during the high flow period under current conditions (Figure 4-6). It is recommended that the winter/spring low flow be maintained at 10 ML/d (or natural) between June and November.

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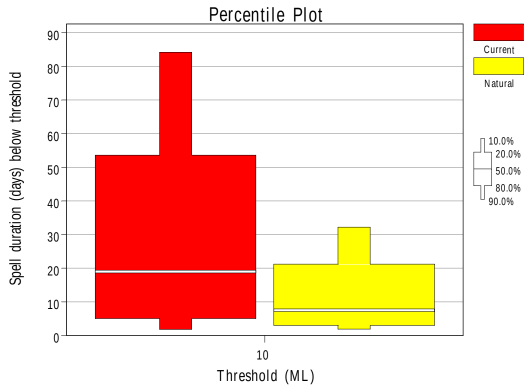
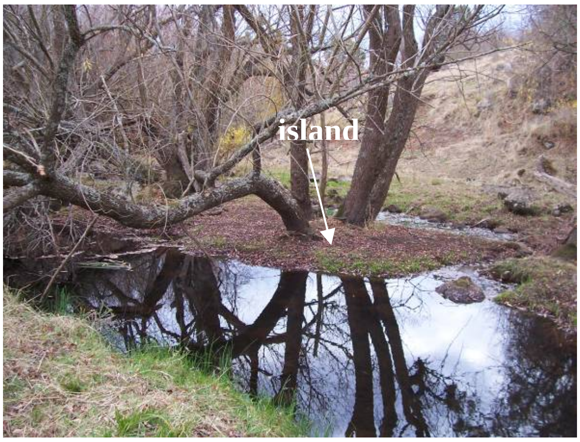
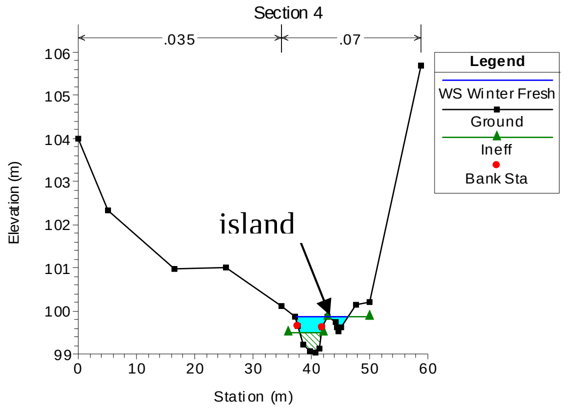


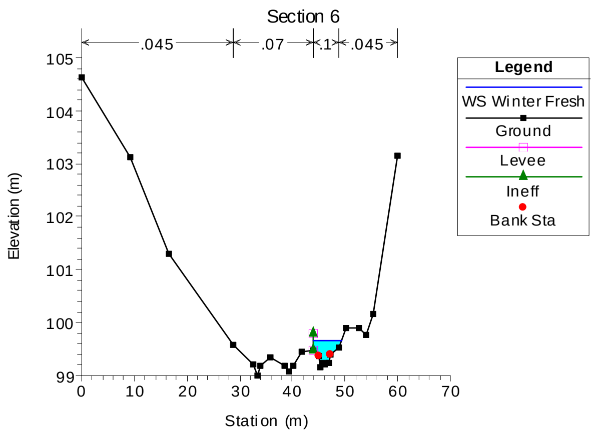
- **Figure 4-6 Duration of flows below 10 ML/d under current and natural conditions for Reach 1.**

Winter/spring: freshes

The recommended threshold for a winter/spring fresh is 40 ML/d. At this flow almost all of the channel bottom, aggraded flats and islands in middle of the channel will be inundated (Figure 4-7). As the water level reaches the top of the flats it will entrain willows leaves and suppress encroaching terrestrial vegetation that has been able to colonise the lower channel zone during the low flow period. Smaller channels, with less flow and velocity than the main channel will provide refuge for fish during these higher periods of flow.



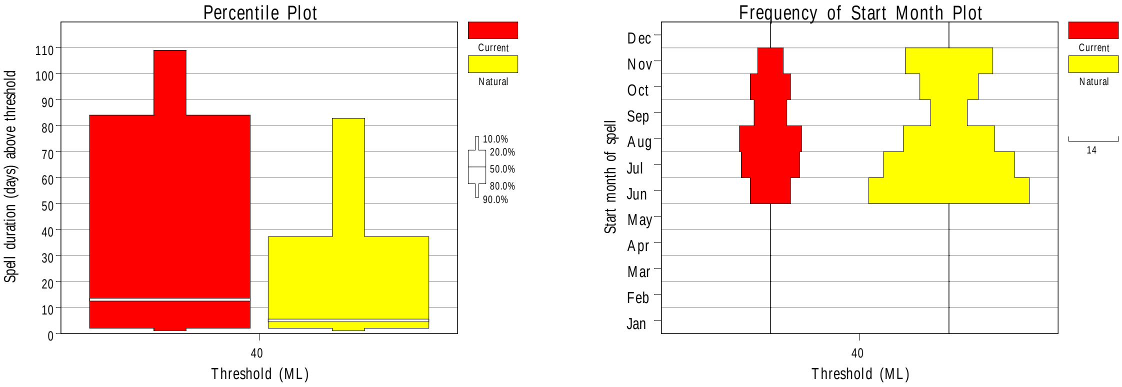




- **Figure 4-7 Photo of island looking downstream (Transect 4, top-left), stage height in pool and over island (Transect 4, above) and stage height in riffle (Transect 6, left) at the recommended threshold for winter/spring freshes at Site 1.**

There has been a dramatic change in the frequency and duration of winter/spring freshes from that experienced under natural conditions due to Newlyn Reservoir capturing these events (Figure 4-8). The frequency of these events now occurs for less than half of the time under natural conditions. However, the median duration of these events has increased from about five to 13 days under current conditions, due to the complete harvesting of shorter events. The timing of these flows has also changed with the majority of flows occurring in June and November now occurring in July and August.

It is recommended that the frequency and duration of winter/spring freshes should more closely replicate natural conditions. Freshes need to occur more than once in a season for them to be ecologically meaningful and three during the winter/spring low flow period should be sufficient. A median duration of five days is recommended to facilitate movement between the pools and flush any sediment that may have accumulated on the willow mats.



- **Figure 4-8 Duration (left) and start month (right) of flows above 10 ML/d for winter/spring freshes under current and natural conditions for Reach 1.**

Winter/spring: high flow

A high flow of 160 ML/d is recommended for Reach 1 downstream of Newlyn Reservoir. This flow will almost fill the entire main channel and provide more depth in the smaller channels and aggraded flats (Figure 4-9). At some transects water will spill out of the deeply incised channel and onto the grassy banks providing refuge for small fish. Velocities will reach over 0.4 m/s in the riffles, thereby enabling the transport of fine sediment that has accumulated amongst the cobbles and willow root mats (Gordon *et al.*, 1992).

Outputs from the HEC-RAS model at Site 1 indicate that at Transect 2, flow would spill out of the incised channel. At Transect 3, the full width of the riffle would be inundated and the lower part of the island to a depth of 75 cm (Figure 4-9).

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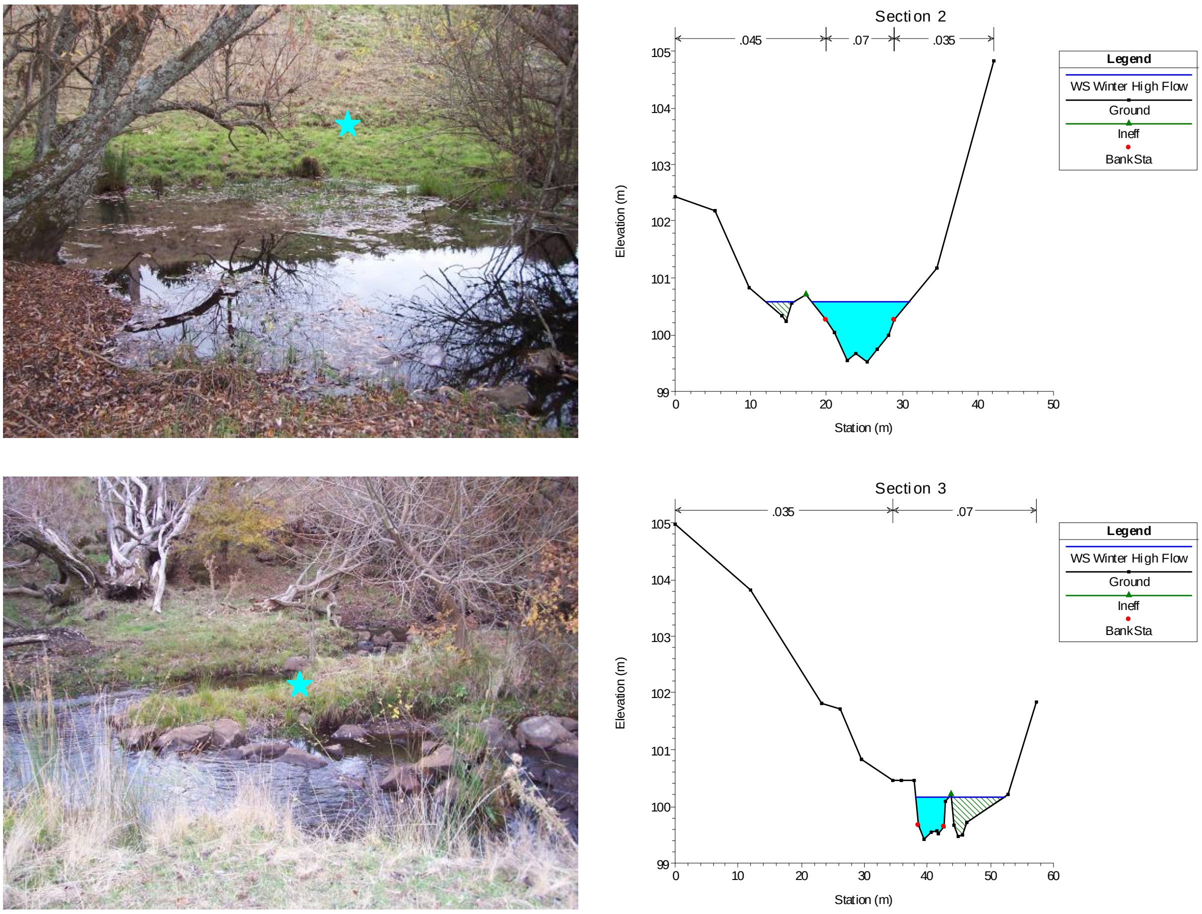
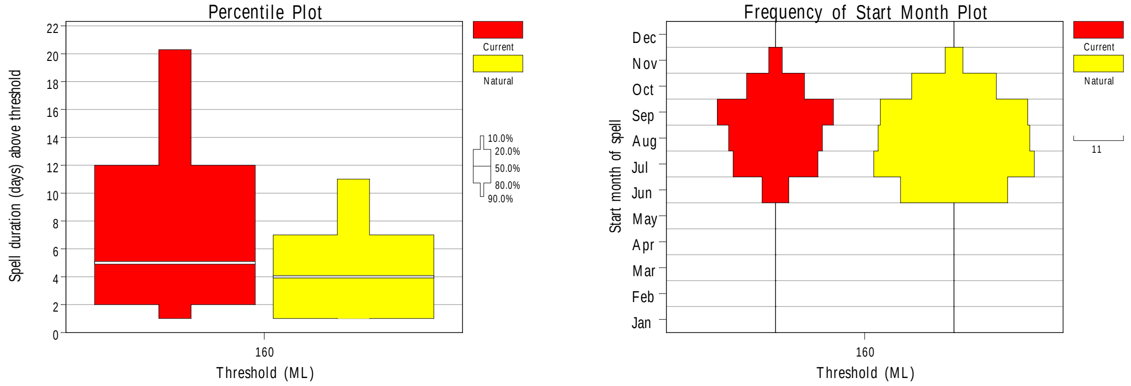


- **Figure 4-9 Photo of pool (top-left) and stage height in pool at Transect 2 (top-right) at the recommended threshold for winter/spring freshes at Site 1 (top-right). Photo of riffle (bottom-left) and stage height in riffle at Transect 3 (bottom-left) at the recommended threshold for winter/spring freshes at Site 1 (blue star indicates approximate recommended water level).**

Under natural conditions flows exceeding 160 ML/d occurred for a median of three times per year, however under current conditions this frequency has been reduced to twice a year (Figure 4-10). However, the median duration has slightly increased under current conditions from four to five days. Under current conditions, high flows occur less during the start of winter/spring, but the general pattern between current and natural has remained very similar. It is recommended that a high flow occur three times year for a minimum duration of five days in order to mimic the natural frequency.



▪ **Figure 4-10 Duration (left) and start month (right) of flows above 160 ML/d for winter/spring high flows under current and natural conditions for Reach 1.**

Winter/spring: bankfull and overbank flows

In Reach 1 it is difficult to determine where the bankfull flow level is due to the structure of the highly modified channel.

Recommendations for a bankfull and overbank flow have not been specifically made for this reach. As the surrounding land is highly modified and cleared of vegetation, the aggraded flats and islands within the current channel perform the necessary ecological functions.

4.1.3 Current compliance with recommendations

Compliance with flow recommendations in Reach 1 is presented in Table 4-3. Under current conditions no flow recommendation volumes are complied with. The recommended summer and winter fresh volumes are currently met in less than 80% of years and the recommended duration is met in 35% and 65% of events respectively. The winter high flow volume is only met in 70% of years, and when it does occur, the duration meets the recommended duration in 50% of events. Under natural conditions, a flow of the recommended magnitude (160 ML/d) would have occurred three times a year.

For comparative purposes, all recommended flows, except the winter low, are above the natural equivalent (i.e. 20th, 50th and 80th natural percentile volumes).

- **Table 4-3 Compliance of the current flow regime in Reach 1 with flow recommendations.**

Flow recommendations			Percentage of years (vol and no.) or events (dur.) when flow recs. are complied with for the current flow regime	Differences between each flow component for the current and natural flow regime for comparative purposes	
Component	Flow recommendation			Current equivalent	Natural equivalent
Summer/autumn (December – May)					
Summer low	**Volume**	3	53	2	1
Summer fresh	**Volume**	10	75	3	4
	Frequency	4	15	2	4
	Duration	3	35	2	5
Winter/spring (June – November)					
Winter low	**Volume**	10	60	4	12
Winter fresh	**Volume**	40	85	17	35
	Frequency	3	20	2	4
	Duration	5	65	13	5
Winter high	**Volume**	160	70	89	89
	Frequency	3	30	2	3
	Duration	5	50	5	4
Winter bankfull	No recommendation				
Winter overbank	No recommendation				

4.1.4 Supporting recommendations

The channel geometry and condition of aquatic habitat in Reach 1 is profoundly influenced by the invasion of willows into the channel and riparian zone and will have an impact on the achievement of the flow objectives. The aquatic habitat and general condition in this reach will benefit from extensive willow removal and revegetation with native species. These works together with a varied flow regime will allow the channel to revert back to the natural planform and perhaps even its former hydraulic geometry.

Newlyn Reservoir has been identified as a site of potential cold water pollution although adequate data is not available to confirm this (Ryan *et al.*, 2001). This issue needs to be investigated, with temperature monitoring at sites downstream of the outlet, as cold water releases have the potential to interfere with the achievement of objectives (i.e. breeding of River Blackfish).

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4.2 Reach 2: Hepburn Race to Lawrence weir

4.2.1 Current condition

The current condition of Reach 2 was detailed in the *Issues Paper*. A summary of the current condition is provided in Table 4-4.

- **Table 4-4 Current condition of Reach 2: Hepburn Race to Lawrence weir.**

Aspect	Current condition
Hydrology	▪ Mean annual flow has been reduced by about 23% ▪ Mid-level and very low flows have been most impacted
Geomorphology	▪ Streamform is influenced by the invasion of willows ▪ Rock steps are present and cattle are the major cause of erosion
Water quality	▪ Potentially high nutrient concentrations downstream of Hepburn Lagoon
Fish	▪ Four native fish species expected – River Blackfish, Mountain Galaxias, Flatheaded Gudgeon and Australian Smelt
Macroinvertebrates	▪ AUSRIVAS Band A, borderline clean water (from SIGNAL index) and borderline number of families for edge and riffle habitats
Instream and riparian flora	▪ Narrow band of riparian vegetation consisting mostly of exotic species ▪ Diverse instream macrophyte community

4.2.2 Flow recommendations

The environmental flow recommendations for Reach 2 are summarised in Table 4-5. No cease to flow recommendation has been made because the environmental benefit of such a flow in this reach is considered negligible, particularly given the degraded condition of the system and the relatively low natural frequency of cease to flow events.

- **Table 4-5 Summary of flow recommendations for Reach 2: Hepburn Race to Lawrence weir.**

Stream		Birches Creek		Reach	Hepburn Race to Lawrence weir		
Compliance point		Smeaton Gauge		Gauge No.	407227		
Season	Component	Magnitude	Frequency	Duration	Rise	Fall	Objective
Summer	Low flow	5 ML/d (or natural)	1 per year	6 months			M2-1, F2-1, V2-1, V2-3
	Freshes	15 ML/d	4 per year (or natural)	3 days	332%	60%	M2-2, F2-2, V2-2, V2-4
Winter	Low flow	10 ML/d (or natural)	1 per year	6 months			M2-1, F2-1, V2-1
	Freshes	55 ML/d	3 per year (or natural)	5 days	332%	60%	M2-2, F2-2, V2-2, V2-4
	High	275 ML/d	2 per year (or natural)	3 days	332%	60%	M2-3, V2-5

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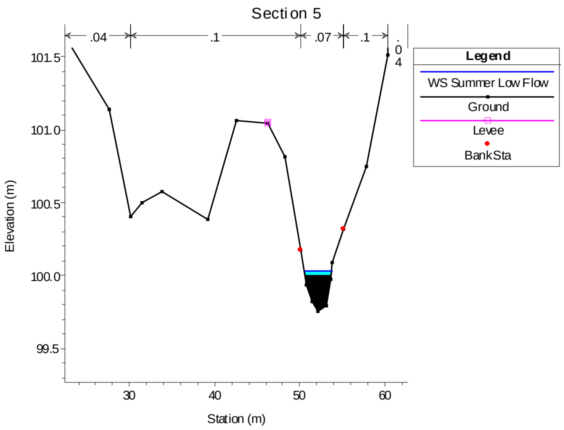
Summer/autumn: low flow

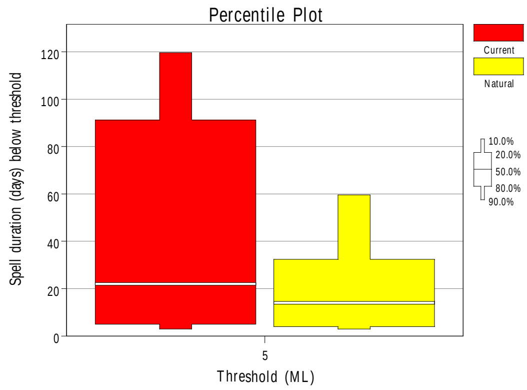
A low flow of 5 ML/d is recommended for Reach 2. This low flow recommendation will maintain adequate habitat throughout the site to ensure the survival of aquatic biota. The flow observed on the day of the field assessment (5 ML/d at Smeaton gauge) was considered adequate for this purpose at the shallowest riffle, Transect five, even though the criteria for determining minimum habitat (a depth of 10 cm at the shallowest riffle) was not met. Flows at this level were considered to be high enough to allow limited longitudinal connectivity and terrestrial organic matter to accumulate on the lower channel for later entrainment into the system at higher flows.

Outputs from the HEC-RAS model at Site 2 indicate that this flow would provide a minimum depth of 3 cm at Transect five (Figure 4-11). However depth across the full width of the riffle is more variable than represented in the model and the maximum depth could be as much as 10 cm or more.



- **Figure 4-11 Photo (left) and model (right) of riffle at Transect 5 at the recommended threshold for summer/autumn low flows at Site 2. Photo taken on the day of the field assessment at which the flow is the recommended 5 ML/d at Smeaton gauge.**

The primary function of a summer/autumn low flow is to maintain minimum habitat conditions for biota so flow should be kept above this threshold for as long as possible. Under natural conditions, flow in this reach of the stream would have fallen below the recommended low flow threshold twice a year and for a median duration of 12 days. Under current conditions this frequency is the same but occurs for a longer duration (22 days) (Figure 4-12). It is recommended that the summer/autumn low flow be maintained at 5 ML/d (or natural) between December to May.

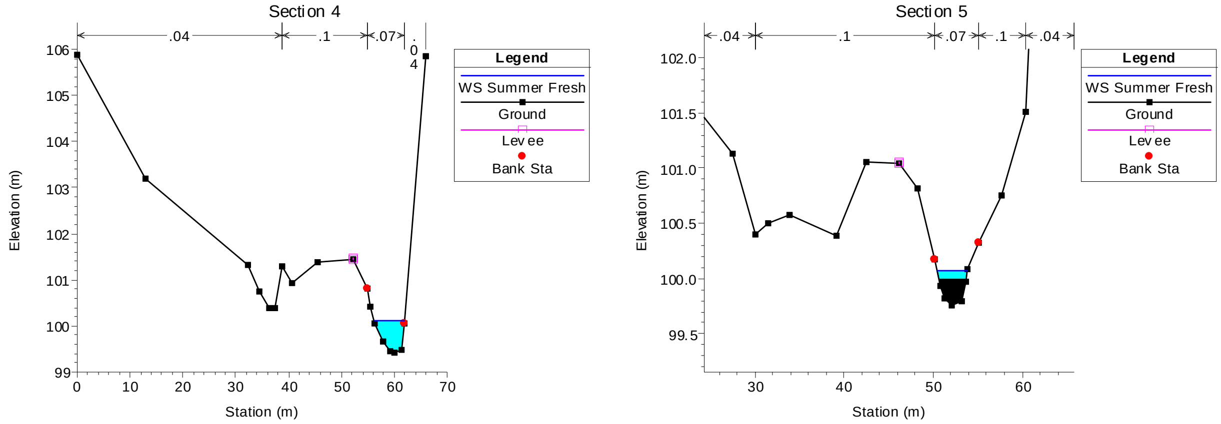


- **Figure 4-12 Duration of flows below 5 ML/d under current and natural conditions for Reach 2.**

Summer/autumn: freshes

The recommended flow for providing a fresh in Reach 2 during summer/autumn is 15 ML/d. This flow will increase depth in the riffles and wet emergent and marginal aquatic vegetation that has been drying out over the low flow period. Fish passage is not a large issue in this reach as of all the fish species that have been recorded are small bodied and unlikely to venture long distances into shallow run reaches. However, water quality in the pools would benefit from a refresh during summer/autumn low flow period.

Outputs from the HEC-RAS model indicate that the channel at this site is confined and large increases in flow are required to produce similarly large increases in stage height and channel width. During these freshes water depth and riffle width at Transect five will increase from the low flow level by around 4 cm and 15 cm respectively (Figure 4-13). Velocities between 0.02 and 0.82 m/s and should be sufficient to refresh pool water quality.



- **Figure 4-13 Stage height in pool (Transect 4, left) and riffle (Transect 5, left) transects at the recommended threshold for summer/autumn freshes at Site 2.**

The delivery of these freshes can only be through the management of diversions and releases from Newlyn Reservoir and/or Hepburn Lagoon. However the timing of the delivery of these freshes is important given that River Blackfish require a minimum temperature of 16^{o}C in which to initiate spawning. The delivery of freshes should therefore be managed to coincide with natural increases in flow in order to reduce the effects of unnaturally low temperatures from Newlyn Reservoir.

The duration and frequency of low flow freshes has changed significantly from natural. Currently, they occur once a year and for a median duration of three days (Figure 4-14). Under natural conditions they occurred four times a year, for a median duration of eight days. It is recommended that a minimum of four freshes be provided for duration of three days in order to replicate the natural frequency.

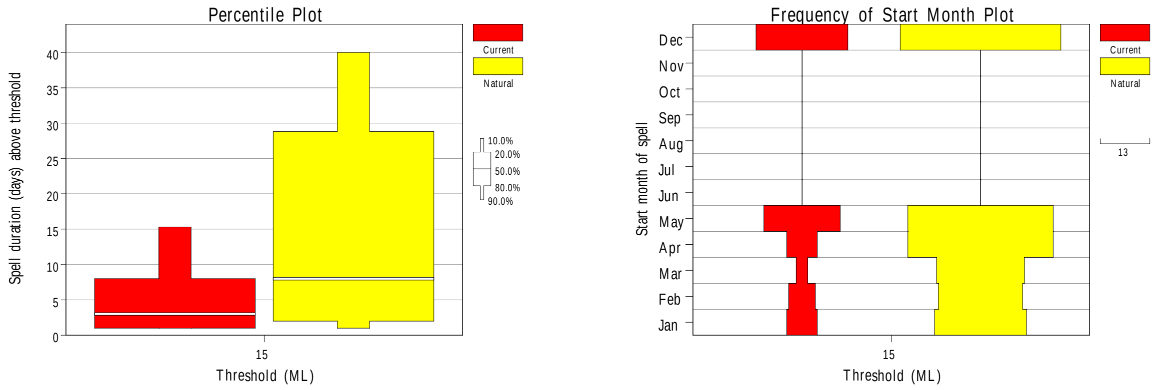


Figure 4-14 Duration (left), and start month (right) of flows above 15 ML/d for summer/autumn freshes under current and natural conditions for Reach 2.

Winter/spring: low flow

At the summer/autumn low flow of 5 ML/d, there is already minimum habitat throughout the site to ensure the survival of aquatic biota. The bottom of riffles are inundated to an average depth of 3 cm at Transects three and five and velocity through these transects averages 0.23 m/s which is adequate for access by small fish. In the pools (Transects one and four) depths average between 0.66 and 1.32 m and velocities are similar to that recorded for River Blackfish resting habitat in Birches Creek (0.02 and 0.04 m/s) (Khan *et al.*, 2004).

Therefore, there appears to be no justification for an increase in magnitude from a summer/autumn low flow to a winter/spring low flow. However, since the natural flow paradigm recognises that natural seasonal variability characterises all ecosystems, winter/spring low flows should be higher than summer/autumn low flows.

A number of flows higher than 5 ML/d were examined in order to determine what would be a suitable increase in flow from the summer/autumn low flow of 5 ML/d. However, given that minimum habitat is provided by the summer/autumn low flow a winter/spring flow of 10 ML/d is recommended in order to preserve the recommendation upstream. This flow increases riffle width by a maximum of 7 cm and pool depth by 1 cm, compared to the summer low flow (Figure 4-15).

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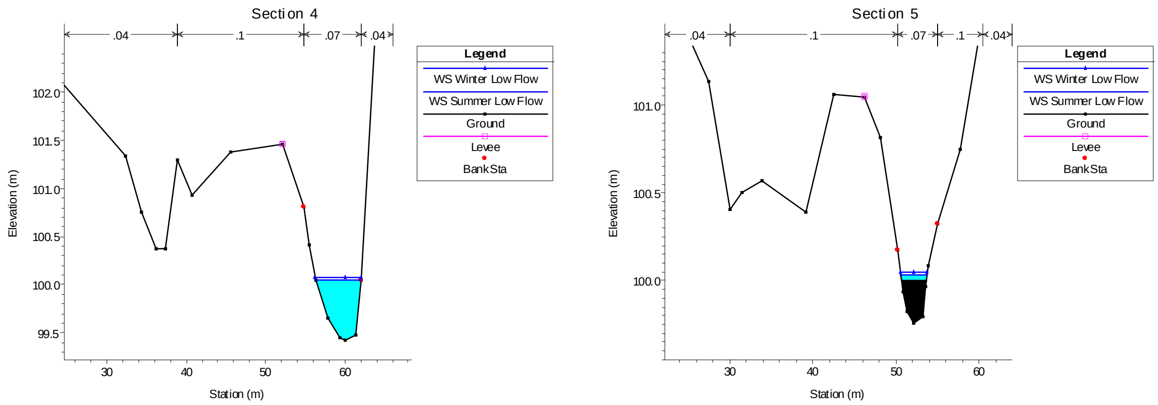
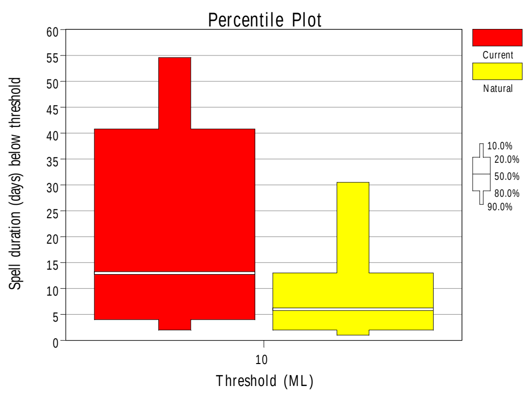


- **Figure 4-15 Differences in stage height in pool (Transect 4, left) and riffle (Transect 5, left) transects at the recommended threshold for summer/autumn low flows and winter/spring low flows at Site 2.**

It is recommended that flow in Reach 2 is maintained above 10 ML/d between June and November, unless natural inflows are lower. The duration and frequency of flow spells that drop below this recommended threshold have increased due to water being harvested in the upper part of the catchment (Figure 4-16). The frequency of these spells should be reduced to the natural frequency of so that they occur no more than once a year.

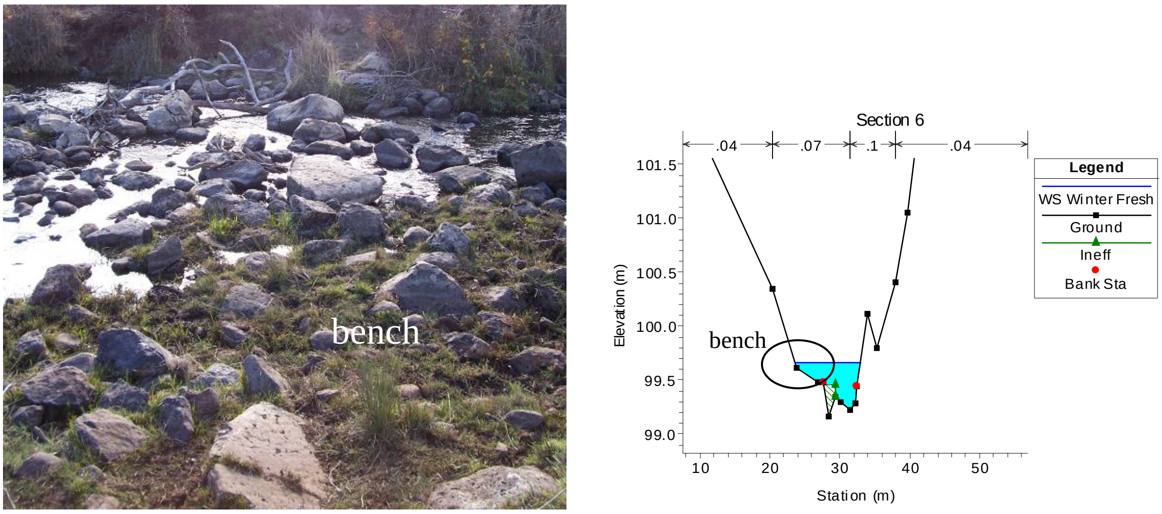


- **Figure 4-16 Duration of flows below 10 ML/d under current and natural conditions for Reach 2.**

Winter/spring: freshes

The recommended threshold for a winter/spring fresh is 55 ML/d. At this flow bank and bench vegetation will be enhanced through the provision of moisture and sediment. Organic cycling within the stream will also be facilitated by moving organic material (both dissolved and leaves and twigs) from the benches and into the stream.

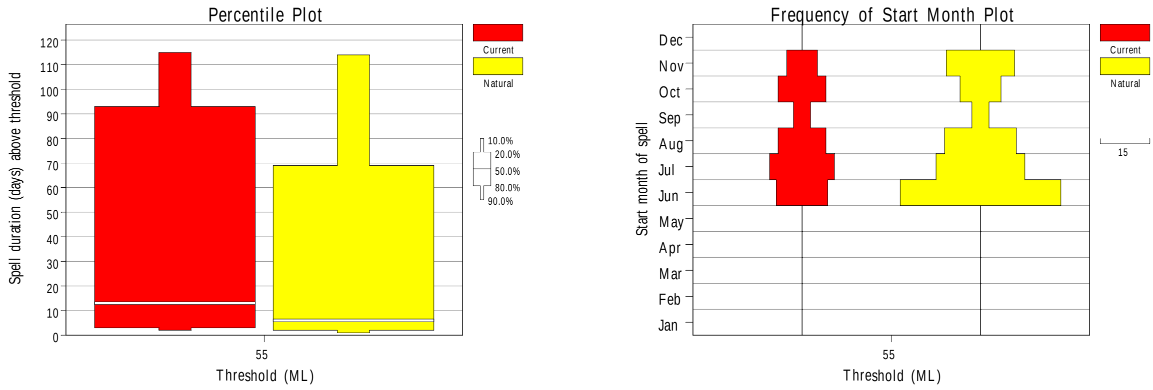
One bench can be identified at this site at Transect six. No significant riparian vegetation occurs on this bench and it is covered in terrestrial grasses and cobbles (Figure 4-17). However over time, this bench may become an area that supports semi aquatic herbs and sedges and which contributes to habitat diversity in this reach. These areas will also provide refuge for small-bodied fish during higher flows.



- **Figure 4-17 Photo looking across riffle and bench (left) and model (right) of riffle looking downstream at Transect 6 at the recommended threshold for winter/spring freshes at Site 2.**

Under natural conditions, flows that exceeded the recommended threshold would have lasted for a median of six days and occurred three times a year (Figure 4-18). Under current conditions, flows exceeding the threshold occur less often, twice a year, but tend to be longer (median 13 days).

It is recommended that the frequency and duration of winter/spring freshes should more closely replicate natural conditions. Freshes need to occur more than once in a season to achieve the ecological functions and three during the winter/spring low flow period should be sufficient. A duration of five days is recommended to wet up the benches.

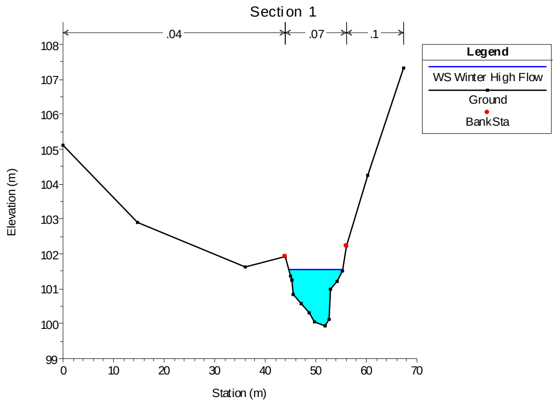


- **Figure 4-18 Duration (left) and start month (right) of flows above the threshold for winter/spring freshes under current and natural conditions for Reach 2.**

Winter/spring: high flow

A flow of 275 ML/d is recommended to provide a high flow in Reach 2 during the winter/spring period. This flow will provide more depth in the pools and provide lateral connectivity between the stream and high flow channels throughout the reach.

Outputs from the HEC-RAS model indicate that this flow will inundate the lower part of the high flow channel at Transect 1 (Figure 4-19) and the smaller side channel and Transect 6. The inundation of these features will provide additional habitat for fish and macroinvertebrates and allow localised movement of River Blackfish in the lead up to the breeding season. Channel velocities range from a maximum of 0.68 m/s in the pools to 1.81 m/s in the riffles, thereby enabling the transport of fine sediment that may have accumulated in the riffles (Gordon *et al.*, 1992).



- **Figure 4-19 Photo looking downstream (left) and stage height of pool looking downstream (right) (Transect 1) at the recommended threshold of a winter/spring high flow at Site 2 (blue star indicates approximate recommended water level. Flow on day of photo was 5.5 ML/d at Smeaton gauge).**

Under natural conditions, flows that exceeded the recommended threshold of 275 ML/d would have occurred four times a year and lasted for an average of three days during the high flow period (Figure 4-20). Under current conditions, flows exceeding this threshold occur less often, twice a year, but for a longer duration (median four days). The timing of these flows has not changed.

It is recommended that a high flow occur twice a year for a minimum duration of three days. This was considered sufficient even though under natural conditions these flows occurred more frequently. A more frequent occurrence was deemed to be unnecessary in this reach given that the surrounding land is highly modified and cleared of vegetation.

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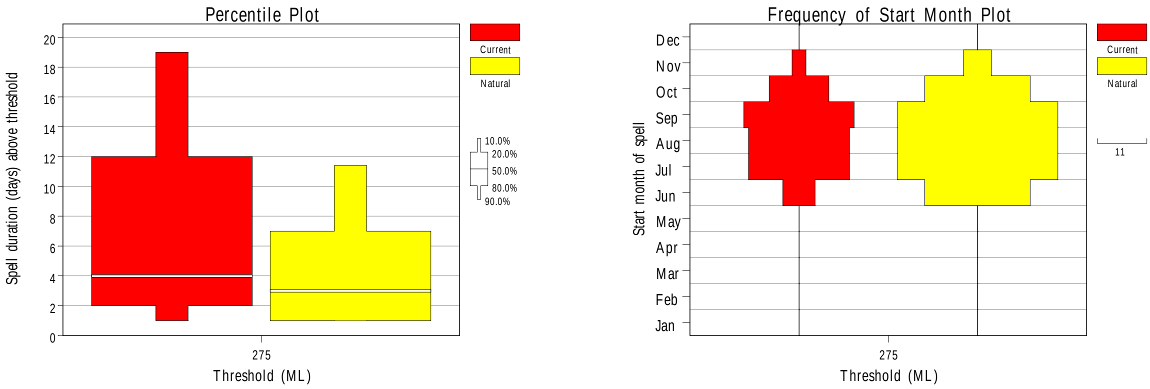


- **Figure 4-20 Duration (left) and start month (right) of flows above 275 ML/d for summer/autumn high flows under current and natural conditions for Reach 2.**

Winter/spring: bankfull/overbank flow

As for Reach 1, recommendations for a bankfull/overbank flow are not made for this reach. As the surrounding land is highly modified and cleared of vegetation, the ecological functions of an overbank flow and floodplain are thought to be performed by the bench and high flow channel.

In any case, such high flow events may not be able to be managed and may be delivered when Newlyn Reservoir spills. However there is insufficient data available in order to determine how often Newlyn Reservoir does spill.

4.2.3 Current compliance with recommendations

Compliance with flow recommendations in Reach 2 is presented in Table 4-6. Under current conditions no flow recommendation volumes are complied with. The summer low flow is met 38% of the time under current conditions, with the 80th percentile current and natural flow both 3 ML/d. The winter low flow is met 99% of the time under current conditions, with the 80th percentile current and natural flow, 8 and 21 ML/d respectively.

The summer fresh volume is currently met in 70% of years, but the frequency of events is only met 5% of the time, and of those events, the recommended duration is only met in 10% of events.

The winter fresh volume is met in 90% of years but the duration is only met in 60% of years with a current median duration of 13 days compared to a recommended duration of five days. The median duration of the winter fresh under natural conditions is six days, however the median number of winter fresh events is three.

The summer high flow is currently met in 70% of years but the duration is only met in 65% of events. The current median duration is four days compared to the recommended duration of three days, and a median duration of four days under the natural flow regime.

Table 4-6 Compliance of the current flow regime in Reach 2 with flow recommendations.

Flow recommendations: Component	Flow recommendation		Percentage of years (vol and no.) or events (dur.) when flow recs. are complied with for the current flow regime	Differences between each flow component for the current and natural flow regime for comparative purposes: Current equivalent	Natural equivalent
Summer/autumn (December – May)					
Summer low	**Volume**	5	38	3	3
Summer fresh	**Volume**	15	70	4	10
	Frequency	4	5	1	4
	Duration	3	50	3	8
Winter/spring (June – November)					
Winter low	**Volume**	10	99	8	21
Winter fresh	**Volume**	55	90	36	61
	Frequency	3	15	2	3
	Duration	5	60	13	6
Winter high	**Volume**	275	70	156	156
	Frequency	2	60	2	4
	Duration	3	65	4	3
Winter bankfull	No recommendation				
Winter overbank	No recommendation				

4.2.4 Supporting recommendations

A number of rock weirs have been constructed at Site 2. Although some may pool water back to the nearest rock weir or riffle, the pool riffle/cascade sequence is a natural feature of this reach. However one rock weir immediately upstream of Transect two has a maximum drop of about 1 m and may prevent the migration of native fish species. However given flow is still able to pass through this weir and that all four native fish species recorded from this reach are non-migratory it probably does not pose a threat to the distribution of native fish in Birches Creek.

Landuse changes are likely to be an important determinant of health of the macroinvertebrate and instream macrophyte community in this reach. In particular, the degradation of the riparian zone, and stock access to the stream bank may both have an impact on the achievement on the flow objectives. The quantity and quality of riparian vegetation is poor and there is common stock access along the reach. These issues will need to be addressed to assist in achieving the objectives.

4.3 Reach 3: Lawrence weir to Creswick Creek confluence

The current condition of Reach 3 was detailed in the *Issues Paper*. A summary of the current condition is provided in Table 4-7.

Table 4-7 Current condition of Reach 3: Lawrence weir to Creswick Creek confluence

Aspect	Current condition
Hydrology	▪ Mean annual flow has been reduced by about 21% ▪ Mid-level and very low flows have been most impacted
Geomorphology	▪ Incised channel as a result of changed landuse ▪ Varied channel form that includes benches, bars and deeper pools ▪ High load of large woody debris
Water quality	▪ High nutrient concentrations may be due to surrounding landuse
Fish	▪ Two native fish species recorded – River Blackfish and Mountain Galaxias. Flatheaded Gudgeon and Australian Smelt may also occur
Macroinvertebrates	▪ AUSRIVAS Band A and borderline clean water (from SIGNAL index)
Instream and riparian flora	▪ Narrow band of riparian vegetation consisting mostly of exotic species ▪ Diverse instream macrophyte community

4.3.1 Flow recommendations

The environmental flow recommendations for Reach 3 are summarised in Table 4-8. No cease to flow recommendation has been made because the environmental benefit of such a flow in this reach is considered negligible, particularly given the degraded condition of the system and the relatively low natural frequency of cease to flow events.

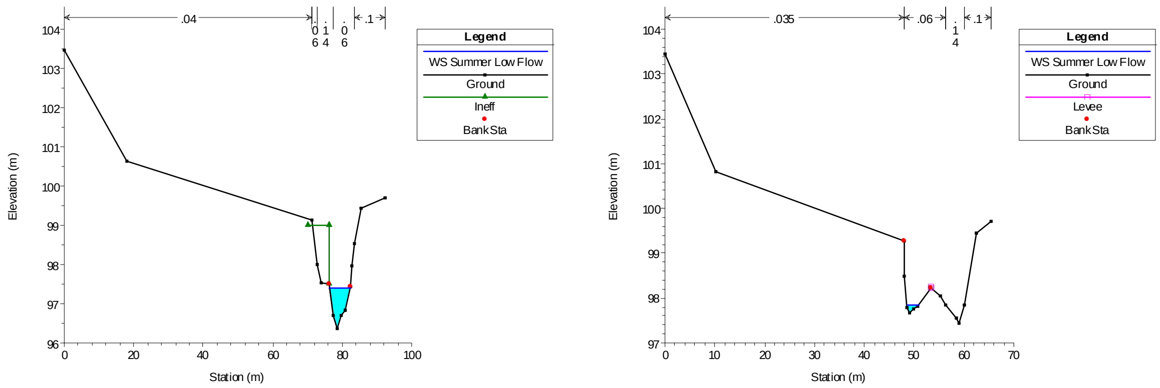
Table 4-8 Summary of flow recommendations for Reach 3: Lawrence weir to Creswick Creek confluence.

Stream		Birches Creek		Reach	Lawrence weir to Creswick Creek confluence		
Compliance point		Confluence of Creswick Creek and Birches Creek (Tullaroop Creek)		Gauge No.	No gauge present		
Season	Component	Magnitude	Frequency	Duration	Rise	Fall	Objective
Summer	Low flow	8 ML/d (or natural)	1 per year	6 months			M3-1, F3-1, V3-1, V3-3
	Freshes	27 ML/d	4 per year (or natural)	4 days	328%	60%	M3-2, F3-2, V3-2, V3-4
	Low flow	20 ML/d (or natural)	1 per year	6 months			M3-1, F3-1, V3-1
Winter	Freshes	65 ML/d	3 per year (or natural)	5 days	328%	60%	M3-2, F3-2, V3-2, V3-4, V3-5
	High	200 ML/d	3 per year (or natural)	3 days	328%	60%	M3-3, V3-5
	Bankfull	1300 ML/d	1 per year (or natural)	1 day	328%	60%	M3-3, V3-5

Summer/autumn: low flow

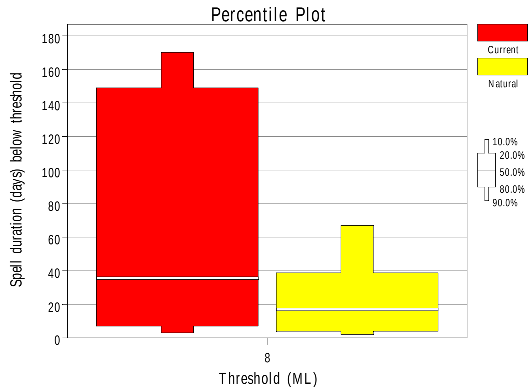
A low flow of 8 ML/d is recommended for Reach 3. This low flow recommendation will maintain adequate habitat throughout the site to ensure the survival of aquatic biota. The criteria for determining the minimum habitat was a minimum depth of 10 cm at the shallowest riffle (Transect three). Flows at this level will maintain deep pool habitat for fish and adequate water depth over the riffles for macroinvertebrates. It will also expose large areas of the streambed, which serves as an important function for nutrient processing by allowing terrestrial organic matter to accumulate on the exposed channel.

Outputs from the HEC-RAS model at Site 3 indicate that flow less than 8 ML/d does not provide a depth of 10 cm at Transect three and would severely reduce the capacity to maintain habitat for instream flora and fauna. A flow of 8 ML/d will maintain deep pools (1 m) for all fish species, including River Blackfish and provide a depth of 16 cm at Transect three (Figure 4-21). This flow produces average velocities between 0.02 and 0.42 m/s.



- **Figure 4-21 Stage height in pool (Transect 6, left) and riffle (Transect 3, right) transects at the recommended threshold for summer/autumn low flows at Site 3.**

The primary function of a summer/autumn low flow is to maintain minimum habitat conditions for biota so flow should be kept above this threshold for as long as possible. Under natural conditions, flow in this reach of the river would have fallen below the recommended low flow threshold less every two years for a median duration of 20 days. Under current conditions this drop occurs at the same frequency but for a longer duration (40 days) (Figure 4-22). It is recommended that the summer/autumn low flow is maintained at 8 ML/d (or natural) between December to May.

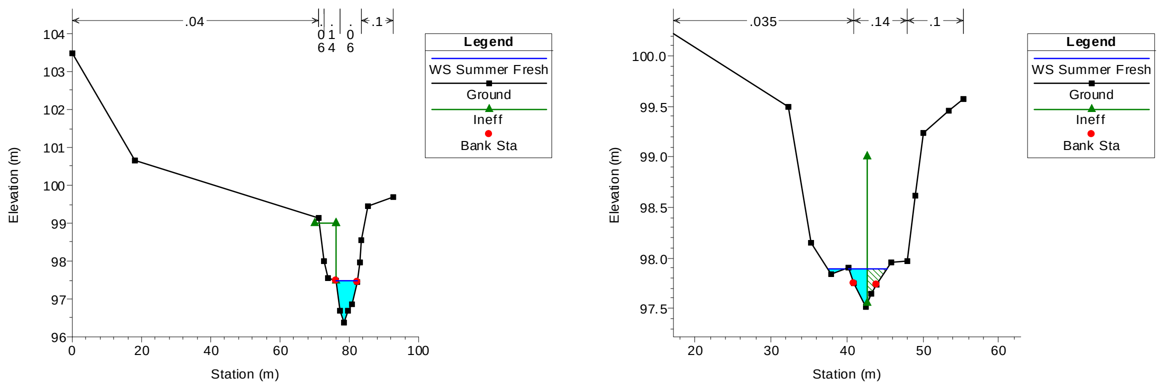


■ **Figure 4-22 Duration of flows below 8 ML/d under current and natural conditions for Reach 3.**

Summer/autumn: freshes

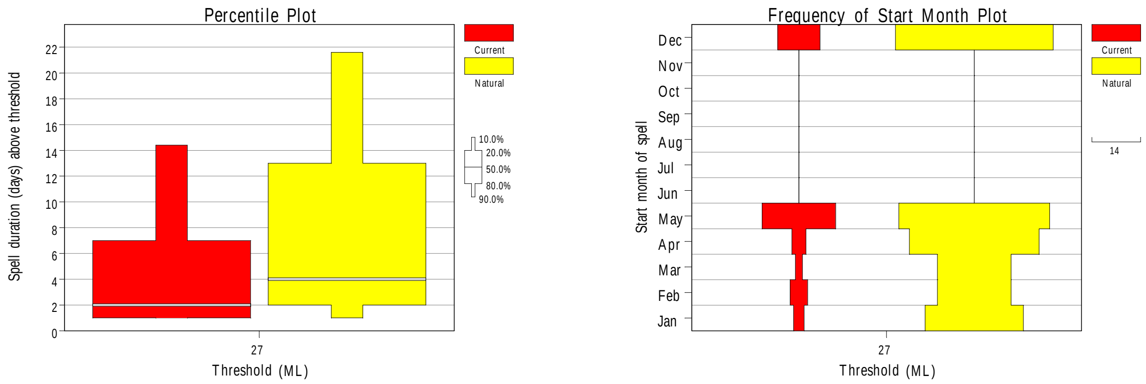
The recommended flow for providing a fresh during summer/autumn is 27 ML/d. Outputs from the HEC-RAS model at Site 3 indicate that this flow will result in some lateral expansion in the riffle/run areas and raise water depths by over 10 cm (Figure 4-23). This increase in depth will also enhance connectivity between pools and allow some fish movement. The mid-level bench at Transect four will also be inundated providing additional low flow habitat (Figure 4-23).

A flow of 27 ML/d produces average velocities between 0.08 and 0.54 m/s in all the transects. These average velocities should, according to Gordon *et al. 1992* move all particle sizes of greater than 0.5 mm (silt and fine to medium sand). This suggests that the freshes would be suitable to maintain substrate conditions, but would also be sufficient to refresh water quality.



■ **Figure 4-23 Stage height in pool (Transect 6, left) and run (Transect 4, right) at the recommended threshold for summer/autumn freshes in Reach 3.**

Development in the catchment has decreased the frequency and duration of flow spells greater than 27 ML/d (Figure 4-24). Under natural conditions these flows occurred four times a year for a median duration of four days. Under current conditions, they now occur only once a year for a median duration of two days. It is recommended that a minimum of four freshes be provided for a duration of four days in order to replicate the natural frequency and provide the maximum benefits.

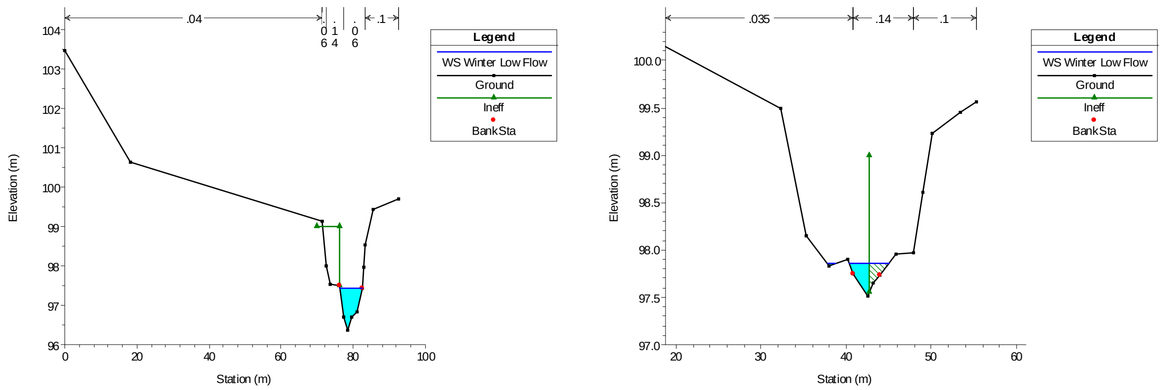


- **Figure 4-24 Duration (left) and start month (right) of flows above 27 ML/d for summer/autumn freshes under current and natural conditions for Reach 3.**

Winter/spring: low flow

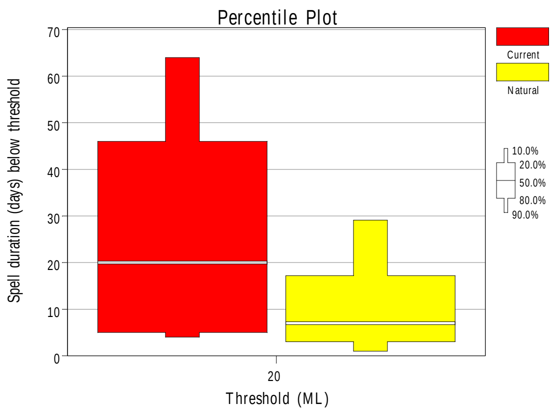
A winter low flow of 20 ML/d is recommended for Reach 3. At this flow the wetted area of the smaller side channels and benches will be sustained (Figure 4-25). This sustained flow will suppress encroaching vegetation such as Cumbungi (*Typha orientalis*) that has been able to colonise the smaller and slower flowing channel during summer low flows while providing ideal conditions for aquatic vegetation, particularly in the spring when many species are entering their growing phase.

Outputs from the HEC-RAS model from Site 3 indicate that water depths across the site increase from the summer/autumn low flow level by around 4 cm (Figure 4-5). This provides more habitat for fish and macroinvertebrates because more habitat features such as undercut banks, benches and woody debris are inundated compared to the summer/autumn low flow period.



- **Figure 4-25 Stage height in pool (Transect 6, left) and run (Transect 4, right) at the recommended threshold for winter/spring low flow at Site 3.**

The duration of flows spells that drop below 20 ML/d recommended threshold have increased with the development in the catchment (Figure 4-26). Under natural conditions, flow in this reach of the stream would have fallen below the recommended threshold for a median duration of seven days compared to 20 days under current conditions. It is recommended that the winter/spring low flow be maintained at 20 ML/d (or natural) between June and November.



- **Figure 4-26 Duration of flows below 20 ML/d under current and natural conditions for Reach 3.**

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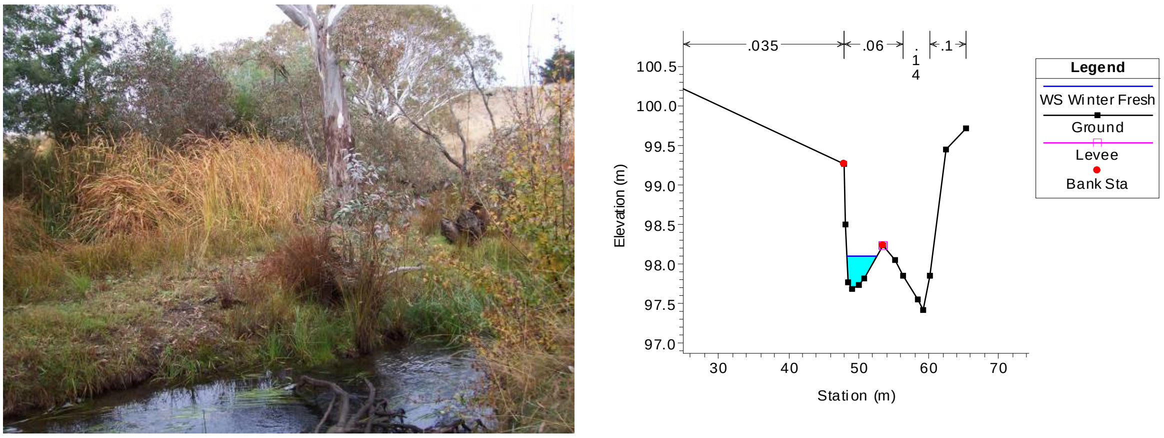
Winter/spring: freshes

The recommended threshold for a winter/spring fresh is 65 ML/d. At this flow almost all of the channel bottom and islands in middle of the channel will be inundated (Figure 4-27). As the water level reaches the top of the islands it will entrain River Red Gum leaves and may have an added benefit of assisting to maintain the heterogeneity of macrophytes in terms of cover, form and species richness. Smaller channels, with less flow and velocity than the main channel will provide refuge for fish during these higher periods of flow.



- **Figure 4-27 Photo of run looking upstream of Transect 3 (left) and model (right) of run looking downstream at Transect 3 at the recommended threshold for winter/spring freshes at Site 3.**

There has been a change in the frequency and duration of winter/spring freshes from that experienced under natural conditions due to Newlyn Reservoir capturing these events (Figure 4-28). The frequency of these events now occurs less than half of the time (one per year compared three per year) under natural conditions. However, the duration of these events has increased from about five to 17 days under current conditions. The timing of these flows has not changed from natural.

It is recommended that the frequency and duration of winter/spring freshes should more closely replicate natural conditions. Freshes need to occur more than once in a season for them to be ecologically meaningful and three during the winter/spring low flow period should be sufficient. A median duration of five days is recommended to facilitate movement between the pools and entrain organic matter.

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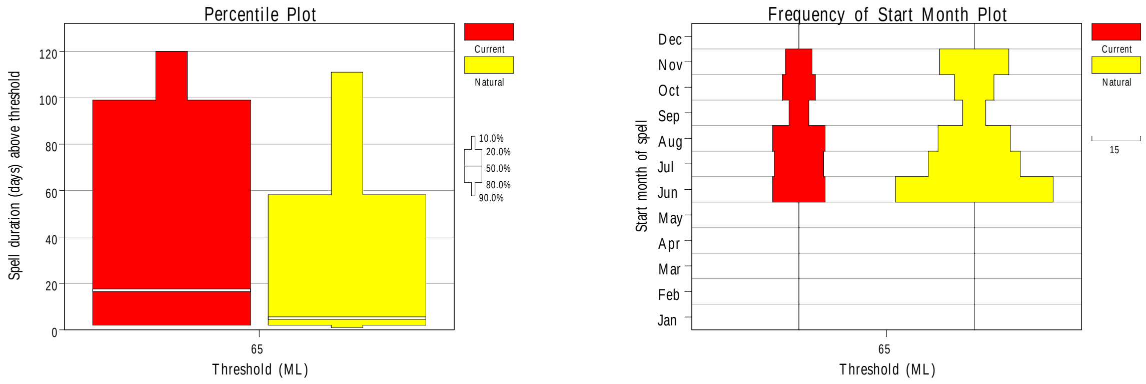

- **Figure 4-28 Duration (left) and start month (right) of flows above threshold for winter/spring freshes under current and natural conditions for Reach 3.**

Winter/spring: high flow

A flow of 200 ML/d is recommended to provide a high flow in Reach 3 during the winter/spring period. This flow will provide more depth in the pools and over benches, provide lateral connectivity between the stream and high flow channels throughout the reach. Carbon cycling within the stream will be facilitated by the movement of riparian zone River Red Gum litter from the benches.

Outputs from the HEC-RAS model indicate that this flow will inundate the island at Transect three and provide more depth over the benches at Transect four (Figure 4-29). The inundation of these features will provide additional habitat for fish and macroinvertebrates and allow localised movement of River Blackfish in the lead up to the breeding season. Channel velocities ranging from a maximum of 0.37 m/s in the pools (Transect six) to 0.60 m/s in the riffle/runs (Transect five) will enable the transport of fine sediment and prevent the accumulation of Cumbungi in the shallower slow flowing areas.

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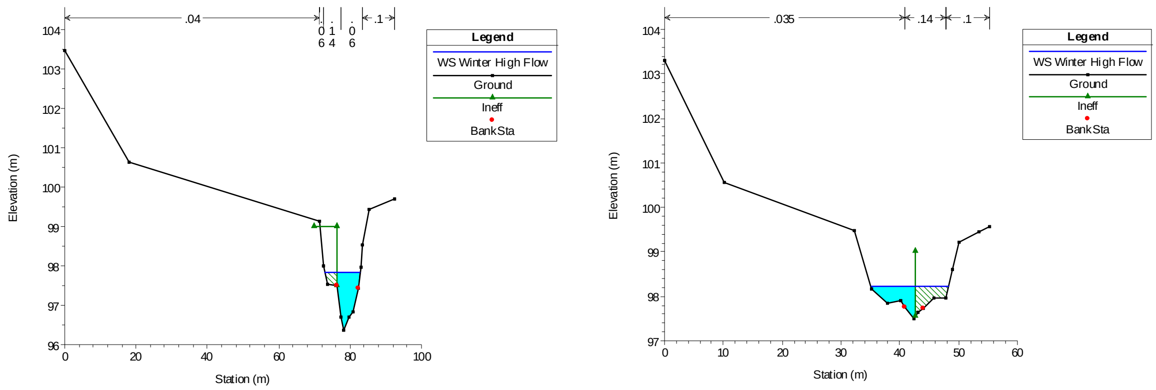
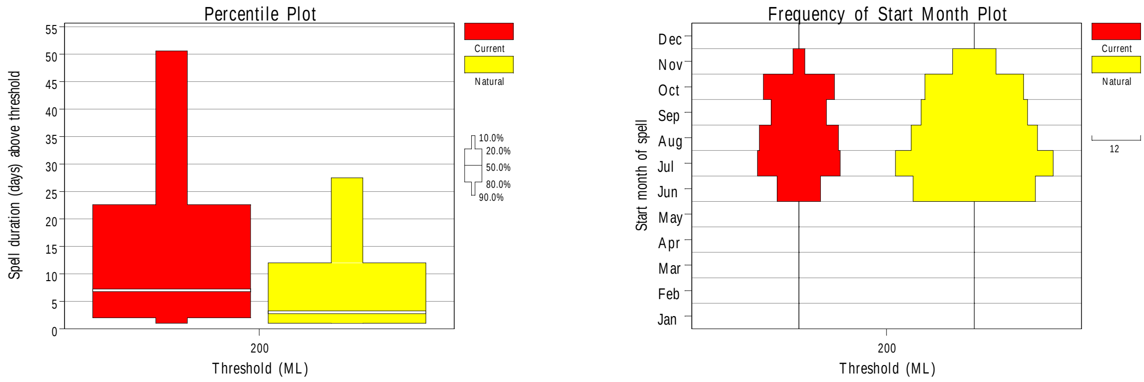


- **Figure 4-29 Stage height in pool (Transect 6, left) and run (Transect 4, right) at the recommended threshold for winter/spring high flow at Site 3.**

There has been a change in the frequency and duration of winter/spring freshes from that experienced under natural conditions due to Newlyn Reservoir capturing these events. The frequency of these events now occurs for approximately than half of the time (two per year compared to less than four per year) under natural conditions (Figure 4-30). However, the duration of these events has increased from a median of three to seven days under current conditions. The timing of these flows has also changed with the majority of flows occurring in July and August now occurring in July and October.

It is recommended that the frequency and duration of winter/spring high flows should more closely replicate natural conditions. High flows need to occur more than once in a season for them to be ecologically meaningful. Two should occur between June and September and one during the growing season, October and November, in order to prevent the accumulation of Cumbungi. A duration of three days will mimic natural conditions.

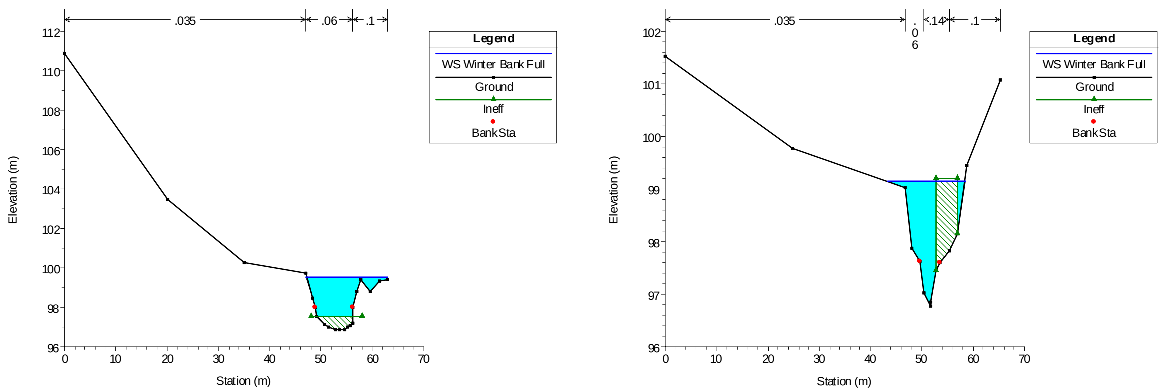


- **Figure 4-30 Duration (left) and start month (right) of flows above 200 ML/d for winter/spring high flows under current and natural conditions for Reach 3.**

Winter/spring: bankfull flow

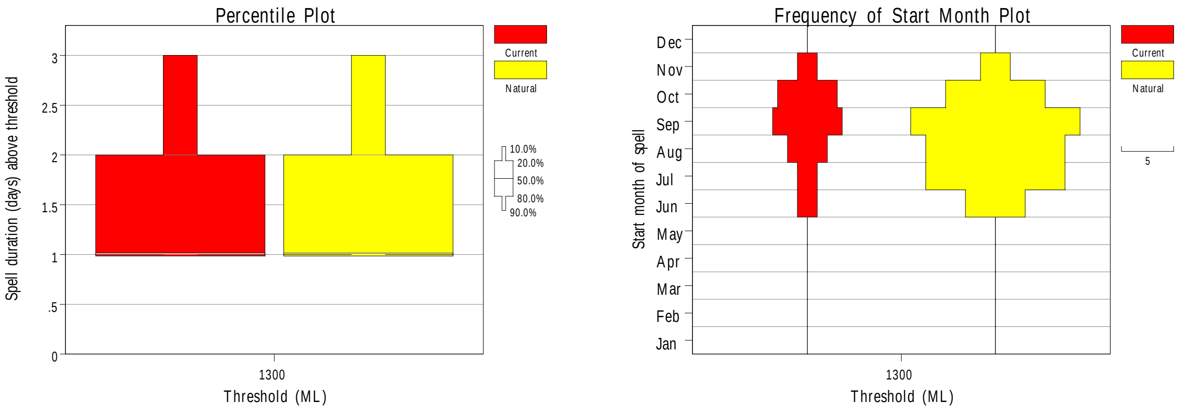
A bankfull flow of 1300 ML/d is recommended for Reach 3. The principal function of this flow is as an ecosystem disturbance. This flow fills the channel, inundating all benches (at Transects one, three and five), disturbing riparian vegetation and transporting sediment (Figure 4-31). This flow will also reach the top of the banks and assist in the regeneration of River Red Gum.

Outputs from the HEC-RAS model at Site 3 indicate that this flow will increase pool depth to over 2 m and produce a maximum velocity of 1.97 m/s at Transect seven.



- **Figure 4-31 Stage height in pool (Transect 2, left) and run (Transect 5, right) at the recommended threshold for winter/spring bankfull flow at Site 3.**

Under natural conditions, flows exceeding 1300 ML/d occurred once a year, however under current conditions they no longer occur 50% of the time. The median duration of one day for bankfull events has not changed with the development of the catchment. Under current conditions, bankfull flows now occur much less frequently during the early part of winter (June and July) (Figure 4-32). It is recommended that bankfull flows be allowed to occur annually with a duration of one day to provide an adequate degree of disturbance.



- **Figure 4-32 Duration (left) and start month (right) of flows above 1300 ML/d for winter/spring bankfull flows under current and natural conditions for Reach 3.**

4.3.2 Current compliance with recommendations

Compliance with flow recommendations for Reach 3 is presented in Table 4-9. Under the current regime the recommended summer and winter low flow volumes are complied 23% and 60% of the time respectively. The summer fresh volume is met in 55% of years and the recommended number of events (four) is met in only approximately 2% of years. The recommended duration is met for 30% of events.

The winter fresh and high flow volumes are complied with 90% and 75% of the time respectively. The frequency is only met in 10% and 30% of years respectively, but the duration is currently higher than that recommended.

Under current conditions, the winter bankfull volume and frequency of events is met in 35% of years. The recommended duration of one day is met for all events that occur. For comparative purposes, the recommended volume of 1300 ML/d occurs less than half of the time under current conditions (i.e. the median frequency is zero).

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- **Table 4-9 Compliance of the current flow regime in Reach 3 with flow recommendations.**

Flow recommendations			Percentage of years (vol and no.) or events (dur.) when flow recs. are complied with for the current flow regime	Differences between each flow component for the current and natural flow regime for comparative purposes	
Component	Flow recommendation			Current equivalent	Natural equivalent
Summer/autumn (December – May)					
Summer low	Volume	8	23	1	4
Summer fresh	Volume	27	55	4	13
	Frequency	4	2	1	4
	Duration	4	30	2	4
Winter/spring (June – November)					
Winter low	Volume	20	60	10	25
Winter fresh	Volume	65	90	42	73
	Frequency	3	10	1	3
	Duration	5	70	17	5
Winter high	Volume	200	75	191	198
	Frequency	3	30	2	4
	Duration	3	75	7	3
Winter bankfull	Volume	1300	35	1300	1300
	Frequency	1	35	0	1
	Duration	1	100	1	1
Winter overbank	No recommendation				

4.3.3 Supporting recommendations

Site 4 is perhaps the most 'natural' looking site visited on Birches Creek due to the North Central Catchment Management Authority's habitat restoration project. However, in general throughout the reach, landuse changes are likely to be an important determinant of health of the macroinvertebrate and instream macrophyte community. In particular, the degradation of the riparian zone, and stock access to the stream bank may both have an impact on the achievement on the flow objectives. The quantity and quality of riparian vegetation is poor and there is common stock access along the reach. These issues will need to be addressed to assist in achieving the objectives.

4.4 Reach 4: Tullaroop Creek from Creswick Creek to Tullaroop Reservoir

The current condition of Reach 4 was detailed in the *Issues Paper*. A summary of the current condition is provided in Table 4-10.

- **Table 4-10 Current condition of Reach 4: Tullaroop Creek from Creswick Creek to Tullaroop Reservoir.**

Aspect	Current condition
Hydrology	▪ Mean annual flow has been reduced by about 21% ▪ Mid-level and very low flows have been most impacted
Geomorphology	▪ Channel is wide and shallow with a series of pools and riffles ▪ Channel is bedrock controlled and therefore not actively adjusting
Water quality	▪ Total nitrogen and total phosphorus concentrations may be elevated due to high nutrient concentrations in Creswick Creek.
Fish	▪ Two native fish species recorded – River Blackfish and Mountain Galaxias. Flatheaded Gudgeon and Australian Smelt may also occur
Macroinvertebrates	▪ AUSRIVAS Band X and doubtful water quality (from SIGNAL index)
Instream and riparian flora	▪ Riparian vegetation has been extensively cleared ▪ Banks are well vegetated by terrestrial grasses

4.4.1 Flow recommendations

The environmental flow recommendations for Reach 4 are summarised in Table 4-11. No cease to flow recommendation has been made because the environmental benefit of such a flow in this reach is considered negligible, particularly given the degraded condition of the system and the relatively low natural frequency of cease to flow events.

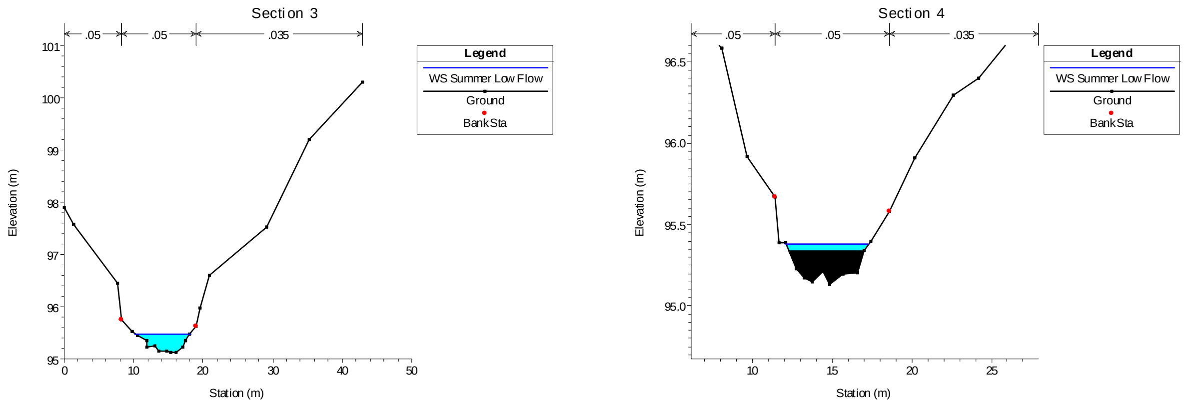
Table 4-11 Summary of flow recommendations for Reach 4: Tullaroop Creek from Creswick Creek to Tullaroop Reservoir.

Stream		Tullaroop Creek		Reach	Creswick Creek to Tullaroop Reservoir		
Compliance point		Tullaroop Creek at Clunes		Gauge No.	407222		
Season	Component	Magnitude	Frequency	Duration	Rise	Fall	Objective
Summer	Low flow	10 ML/d (or natural)	1 per year	6 months			M4-1, F4-1, V4-1, V4-3
	Freshes	23 ML/d	4 per year (or natural)	7 days	322%	60%	M4-2, F4-2, V4-2, V4-4
Winter	Low flow	16 ML/d (or natural)	1 per year	6 months			M4-1, F4-1, V4-1
	Freshes	250 ML/d	3 per year (or natural)	5 days	322%	60%	M4-2, F4-2, V4-2, V4-4
	Bankfull	2580 ML/d	1 per year (or natural)	1 day	322%	60%	M4-3, V4-5

Summer/autumn: low flow

A low flow of 10 ML/d is recommended for Reach 4. This low flow recommendation will maintain adequate habitat throughout the site to ensure the survival of aquatic biota. A minimum depth of 10 cm at the shallowest riffle (Transects two and four) was used as a starting point in determining the minimum habitat.

Outputs from the HEC-RAS model for Site 4 indicate that this flow would provide a minimum depth of 4 cm at Transect four (Figure 4-33). However depth across the full width of the riffle is quite variable and the maximum depth could be as much as 10 cm or more. A maximum depth of 40 cm in the shallowest pool (Transect three) is adequate in providing minimum habitat for all native fish, including River Blackfish. Flows at this level were also considered to be high enough to allow limited longitudinal connectivity and terrestrial organic matter to accumulate on the lower channel for later entrainment into the system at higher flows.



- **Figure 4-33 Stage height in pool (Transect 3, left) and riffle (Transect 4, right) transects at the recommended threshold of summer/autumn low flows at Site 4.**

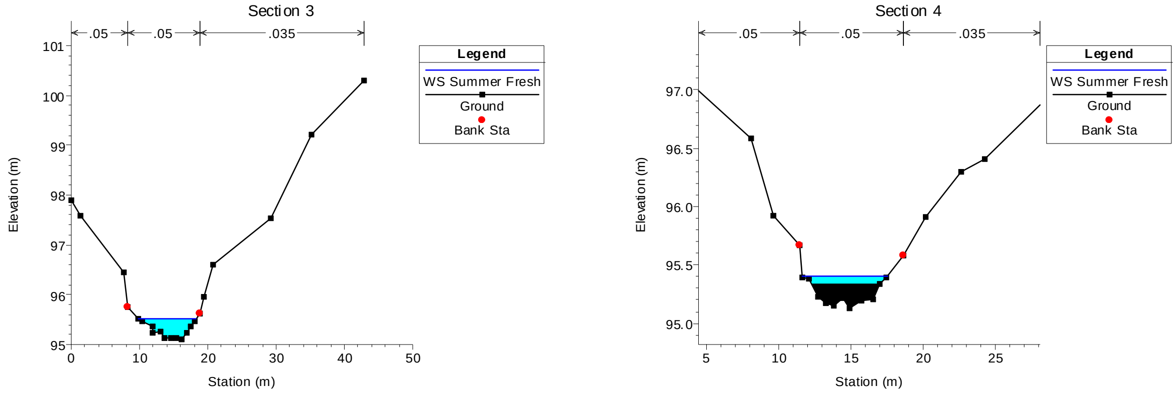
Flows drop below the recommended low flow threshold under both current and natural conditions (Figure 4-34). Under natural conditions, the flow in this reach of the stream would have fallen below the recommended low flow threshold twice a year for a median duration of 10 days. Under current conditions this drop occurs at the same frequency but for a longer duration, with a median of 30 days (Figure 4-2). It is recommended that the summer/autumn low flow be maintained at 10 ML/d (or natural) between December and May.

- **Figure 4-34 Duration of flows below 10 ML/d under current and natural conditions for Reach 4.**

Summer/autumn: freshes

The recommended threshold for low flow freshes in Reach 4 is 23 ML/d. This recommendation is to maintain habitat conditions throughout the site by scouring and preventing the excessive accumulation of biofilm and sediment on the streambed. The criterion for determining the velocity for scouring biofilms is approximately 0.4 m/s (Biggs *et al.*, 1999).

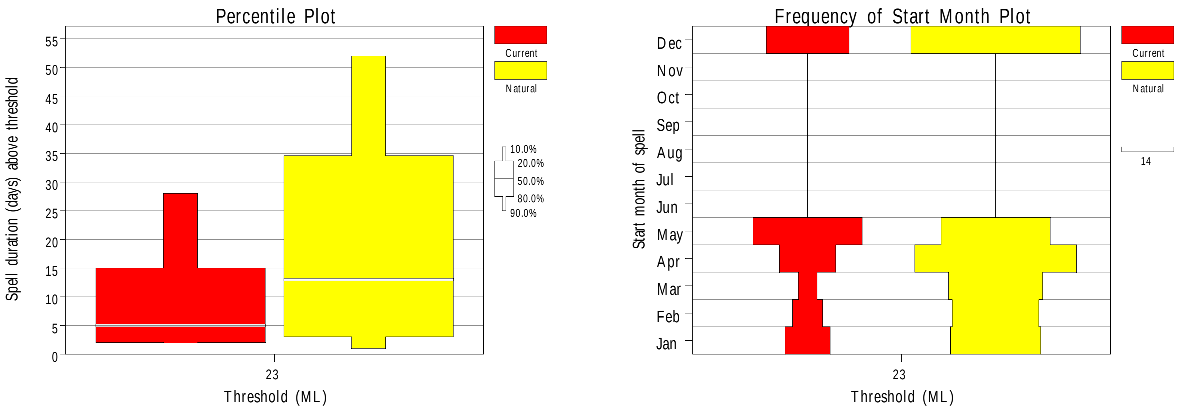
Outputs from the HEC-RAS model for Site 4 indicate that this flow would produce average velocities in the riffles of 0.63 m/s at Transect six and 0.76 m/s at Transect 4 (Figure 4-35). Velocities in the pools are much lower and average 0.09 m/s providing slow flowing habitat for fish. Flows of this velocity are also considered adequate in flushing and turning over pools that may have been deteriorating in water quality during the low flow period.



- **Figure 4-35 Stage height in pool (Transect 3, left) and riffle (Transect 4, right) transects at the recommended threshold for summer/autumn freshes at Site 4.**

Under natural conditions, flows that exceeded the recommended threshold for summer/autumn freshes would have lasted for 13 days and occurred for a median of four times a year (Figure 4-36). Under current conditions, flows exceeding the threshold occur less often, twice a year and for a much shorter duration. The start months above the threshold tend to occur more frequently in May rather than December and April. The decrease in frequency and duration may have significant implications in maintaining favourable habitat and water quality during what is typically the driest period of the year.

It is recommended that low flow freshes be provided for a minimum duration of a week and occur on at least four occasions per year during the low flow period. The ecological benefits provided by freshes only require a relatively short duration and one week is considered adequate to scour biofilms. A frequency of four per year will mimic natural conditions and if spread across the low flow period will help maintain water quality.

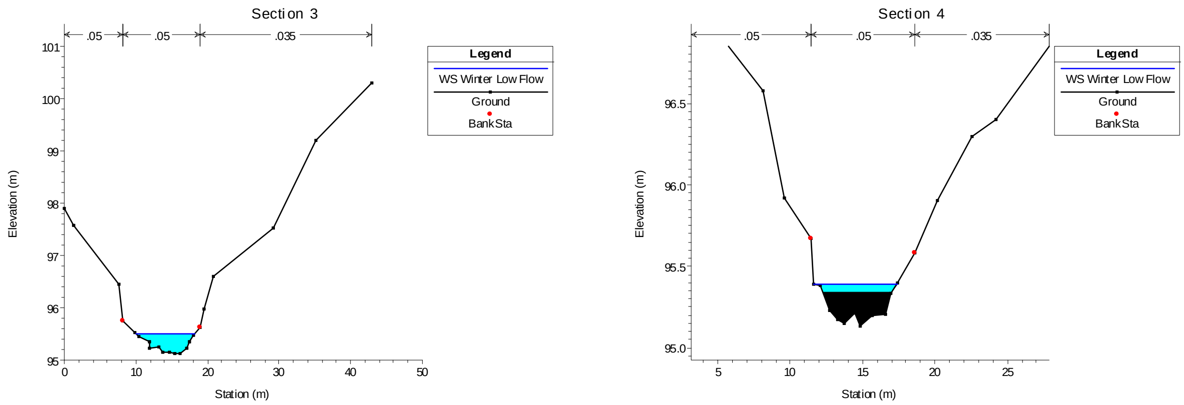


- **Figure 4-36 Duration (left) and start month (right) of flows above 23 ML/d for summer/autumn freshes under current and natural conditions for Reach 4.**

Winter/spring: low flow

A winter/spring low flow threshold of 16 ML/d is recommended for Reach 4. At this flow the majority of the lower channel features and riffles will be inundated (Figure 4-37). This sustained flow will increase the amount of riffle habitat available to macroinvertebrate communities and suppress encroaching grassy terrestrial vegetation that is sensitive to prolonged inundation.

Outputs from the HEC-RAS model for Site 4 indicate that water depths across the site increase from the summer/autumn low flow level by a maximum of 3 cm (Figure 4-37). This provides more habitat for fish and macroinvertebrates because more habitat features such as undercut banks are inundated compared to the summer/autumn low flow period.



- **Figure 4-37 Stage height in pool (Transect 3, left) and riffle (Transect 4, right) transects at the recommended threshold for summer/autumn freshes at Site 4.**

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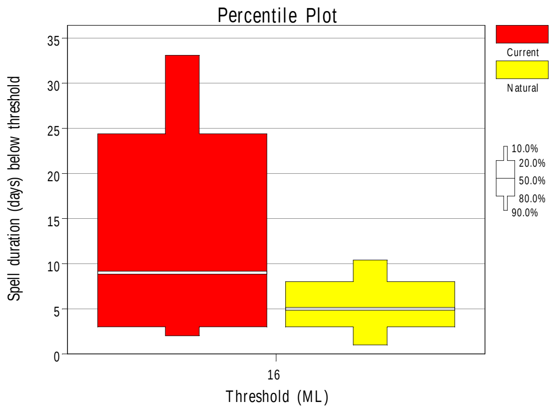
The level of inundation of flows higher than 16 ML/d were examined but were considered to provide relatively little additional benefit given the extra volume of water that are required. However, if the flow drops below this threshold the lower channel portions would not receive sustained wetting and the ecological benefit of the flow would be reduced.

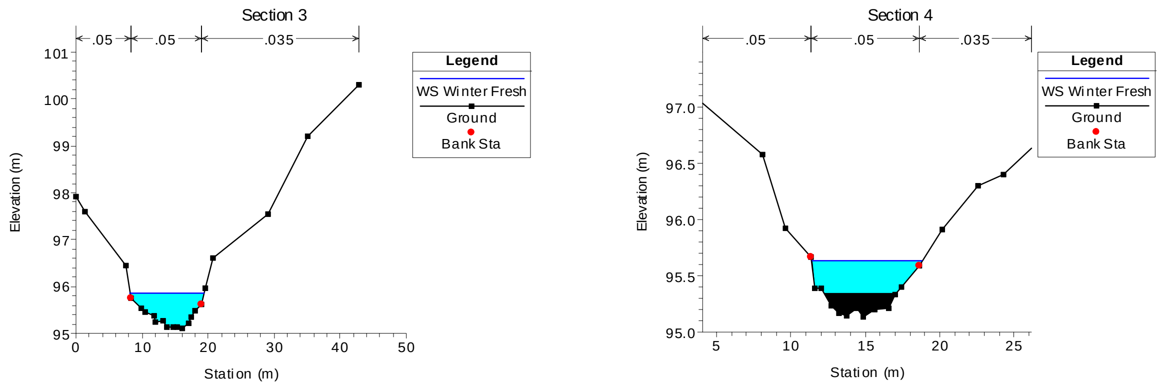
Under natural conditions, flow in this reach of the stream would have fallen below the recommended threshold just once a year and for a median duration of five days (Figure 4-38). Under current conditions this drop occurs more frequently (median twice a year) and for a longer duration. It is recommended that the winter/spring low flow be maintained at 16 ML/d (or natural) between June and November.



- **Figure 4-38 Duration of flows below 16 ML/d under current and natural conditions for Reach 4.**

Winter/spring: freshes

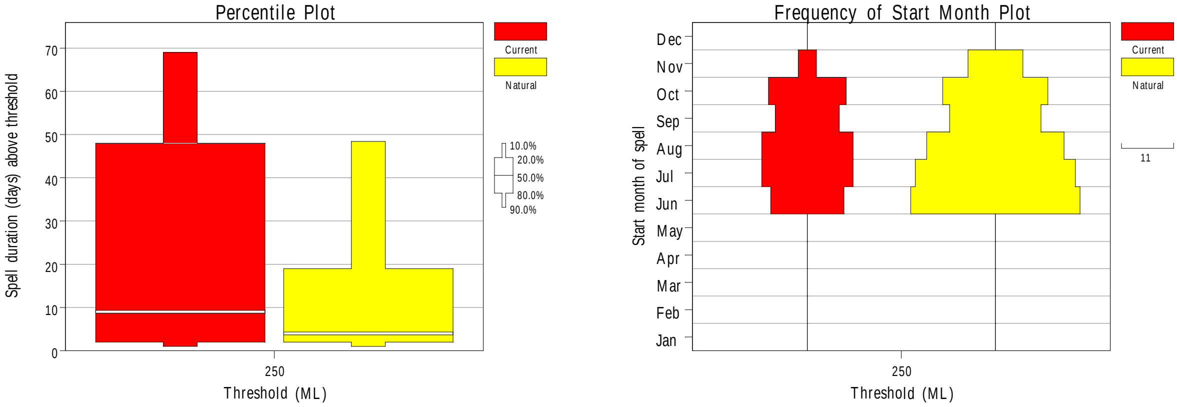
The recommended threshold for a winter/spring fresh is 250 ML/d. At this flow the channel bottom will be inundated, and bank vegetation will be enhanced through the provision of moisture and sediment (Figure 4-39). Longitudinal connectivity will be excellent with water depths above the riffles of over 1 m.



- **Figure 4-39 Stage height in pool (Transect 3, left) and riffle (Transect 4, right) transects at the recommended threshold for winter/spring freshes at Site 4.**

Under natural conditions, flows that exceeded the recommended threshold for winter/spring freshes would have occurred four times a year and lasted for a median duration of five days during the low flow period (Figure 4-40). Under current conditions, flows exceeding this threshold occur less often, median twice a year, but for a longer duration (median 10 days). The start months of flow spells above the threshold tend to occur more frequently in June and July.

It is recommended that high flow freshes be provided for a minimum duration of five days and on at least three occasions per year during the high flow period. The ecological benefits provided by freshes only require a relatively short duration and five days is considered adequate. However, the benefits are only short lived and more than one fresh is required over the winter/spring low flow period. A frequency of three per year will mimic natural conditions and should be delivered to coincide the natural increases in flow.



- **Figure 4-40 Duration (left) and start month (right) of flows above 250 ML/d for winter/spring freshes under current and natural conditions for Reach 4.**

Winter/spring: high

Recommendations for a high flow are not made for this reach. This is because the flow channel is smaller and less incised compared to the other reaches. A low recommendation is made for a bankfull flow which performs the ecological functions of high flow.

Winter/spring: bankfull flow

A bankfull flow of 2580 ML/d is recommended for Reach 4. The principal function of this flow is as an ecosystem disturbance. This flow fills the channel and transports sediment (Figure 4-41).

Outputs from the HEC-RAS model at Site 4 indicate that this flow will increase pool depth to over 2 m and produce a maximum velocity of 1.97 m/s at Transect seven.

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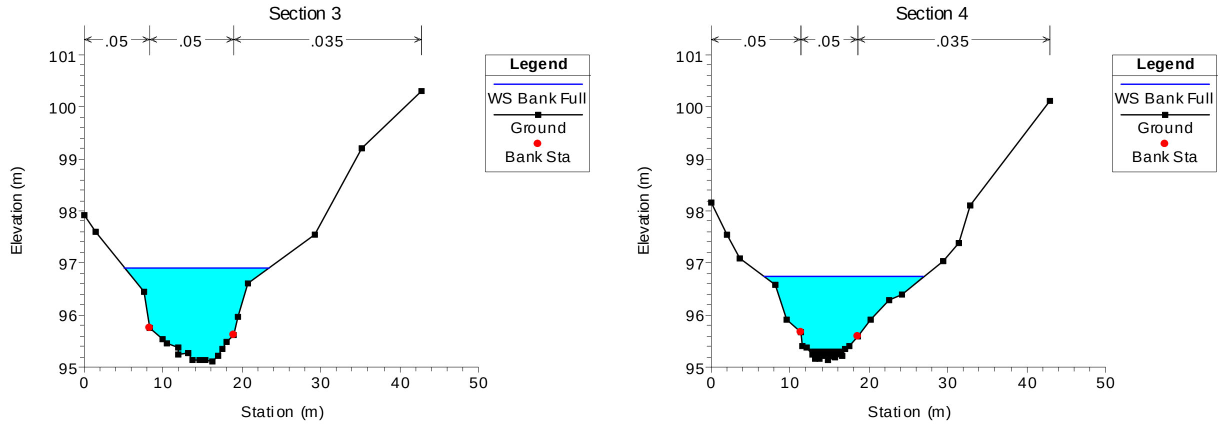
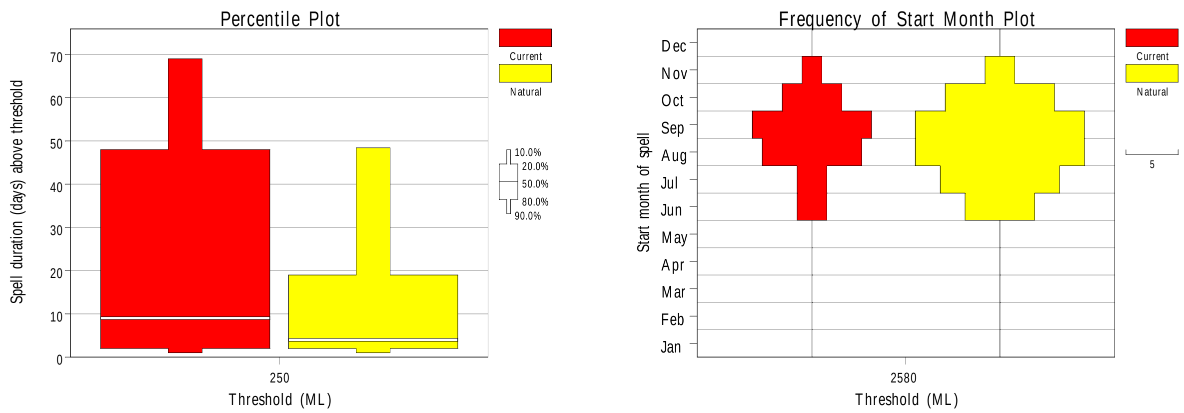


▪ **Figure 4-41 Stage height in pool (Transect 3, left) and riffle (Transect 4, right) transects at the recommended threshold for winter/spring bankfull flows at Site 4.**

Under natural conditions, flows exceeding 2580 ML/d occurred once a year however under current conditions the median frequency is zero (Figure 4-42). The median duration of bankfull events has increased from four to 10 days. Under current conditions, bankfull flows now occur much less frequently during the early part of winter (June and July). It is recommended that bankfull flows be allowed to occur annually with a duration of one day to provide an adequate degree of disturbance.



▪ **Figure 4-42 Duration (top-left), frequency (above) and start month (left) of flows above the threshold for winter/spring bankfull flows under current and natural conditions for Reach 4.**

4.4.2 Current compliance with recommendations

Compliance with environmental flow recommendations for Reach 4 is presented in Table 4-12. Under current conditions the summer low flow recommendation is met 35% of the time and the winter low flow recommendation is met 84% of the time.

The summer fresh volume is met on 80% of occasions but the frequency is only in less than every one in five years (15% compliance) and the duration is only met in 40% of events. The median duration of the summer high flow under natural conditions is 13 days compared with the recommended seven days.

The winter fresh recommendation is complied with in 85% of years. The recommended frequency is three but the current frequency is two. Under natural conditions a winter fresh flow would have occurred four times a year.

Under current conditions, the winter bankfull volume and frequency of events is met in 40% of years. The recommended duration of one day is met for all events that occur. For comparative purposes, the recommended volume of 2580 ML/d occurs less than half of the time under current conditions (i.e. however the median frequency is zero).

- **Table 4-12 Compliance of the current flow regime in Reach 4 with flow recommendations.**

Flow recommendations			Percentage of years (vol and no.) or events (dur.) when flow recs. are complied with for the current flow regime	Differences between each flow component for the current and natural flow regime for comparative purposes	
Component	Flow recommendation			Current equivalent	Natural equivalent
Summer/autumn (December – May)					
Summer low	**Volume**	10	35	2	9
Summer fresh	**Volume**	23	80	7	21
	Frequency	4	15	2	4
	Duration	7	40	5	13
Winter/spring (June – November)					
Winter low	**Volume**	16	84	19	41
Winter fresh	**Volume**	250	85	84	133
	Frequency	3	35	2	4
	Duration	5	60	9	4
Winter high	No recommendation				
Winter bankfull	**Volume**	2580	40	84	133
	Frequency	1	40	0	1
	Duration	1	100	1	1
Winter overbank	No recommendation				

4.4.3 Supporting recommendations

Landuse changes are likely to be an important determinant of health of the macroinvertebrate and instream macrophyte community in this reach. In particular, the degradation of the riparian zone, and stock access to the stream bank may both have an impact on the achievement on the flow objectives. The quantity and quality of riparian vegetation is poor and there is common stock access along the reach. These issues will need to be addressed to assist in achieving the objectives.

5. Conclusions

Environmental flow recommendations were made for each of the four reaches of Birches Creek. The recommendations are to be used in the development of BE conversions in Birches Creek.

The environmental flow recommendations were determined using the framework of the standardised statewide method for determining environmental water requirements in Victoria, referred to as the FLOWS method (DNRE, 2002).

The recommendations were developed to meet the specified environmental flow objectives for macroinvertebrates, fish and instream and riparian flora. These objectives were developed such that, if met, would sustain an ecologically healthy river as defined by the Victorian River Health Strategy (VRHS). Achieving the objectives will also depend on associated catchment works such as controlled management of livestock from the riparian zone, willow removal and revegetation with native species.

The recommendations, only when applied to their full extent, will improve the ecological condition of Birches Creek. The challenge of the BE process is to come up with management alternatives to re-instate the recommended flows that provide a healthy river which meets the environmental, economic, recreational and cultural needs to current and future generations.

6. References

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