



ENVIRONMENTAL FLOW DETERMINATION OF THE STEELS, PAULS AND DIXONS CREEK CATCHMENTS

Final Recommendations

Prepared by

The Steels, Pauls and Dixons Creek Environmental
Flows Technical Panel

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Acronyms/Abbreviations Used in this report:

BE	Bulk water Entitlements
CRC	Co-operative Research Centre
DSE	Department of Sustainability and Environment
FEM	The Flow Events Method
FLAWS	The “Statewide Method for Determining Environmental Water Requirements”
NRE	Department of Natural Resources and Environment (now the Department of Sustainability and Environment).
SDL	Sustainable Diversion Limit.
SFMP	Streamflow Management Plans
SKM	Sinclair Knight Merz Pty Ltd.
Technical Panel	The Steels, Pauls and Dixons Creeks Environmental Flows Technical Panel.
TEDI	Tool for Estimating Dam Impacts.
VHRS	Victorian River Health Strategy

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1. Introduction

This Final Recommendations Report presents environmental flow recommendations for three reaches of the Steels, Pauls and Dixons Creeks determined by the Steels, Pauls and Dixons Creeks Environmental Flows Technical Panel (the “Technical Panel”). The background to the report, study site descriptions and objectives are described in detail in the Issues Paper (SPDEFTP, 2003). It is important that the Final Recommendations be read in conjunction with the Issues Paper.

The study area in this report covered the Steels Creek from Jehosaphat Creek to Dixons Creek confluence (termed Reach 2), Dixons Creek from Brock Spur track to the Steels Creek confluence (Reach 5), and Pauls Creek from the edge of the Toolangi State Forest to the Yarra River (Reach 7).

The study used the general framework of the standardised Statewide method for determining environmental water requirements in Victoria, referred to as the FLOWS method (SKM *et al*, 2002).

Due to a lack of confidence in the available flow data for the three reaches (see Issues Paper, Chapter 5 – SPDEFTP, 2003) full recommendations cannot be made in this report. The environmental flow recommendations are based on the hydraulic modelling component of the FLOWS method (which is independent of the flow data). The recommendations are only expressed as flow rates (ML/d) to achieve certain environmental objectives. It will not be possible to evaluate recommended frequencies and durations for these flow rates.

The Streamflow Management Plan Committee should investigate alternatives for generating adequate natural and current flow data for the catchments. Once this is available, the recommendations will be developed in terms of frequency and durations, allowing an evaluation of the current flows to achieve the recommendations.

Outline of this Report

Section 2 of this report presents an outline of the methods used in this study – the FLOWS method, and the survey techniques employed.

A summary of the Environmental Flow Objectives for the study area is presented in Section 3.

The flow recommendations for each reach are then presented in Section 4 in a standard format with four individual sections:

- A summary of the reach condition (the major environmental issues in the reach);
- The Environmental Flow Objectives for the reach;
- The flow recommendations to achieve the ecological objectives, with justifications;
- Summary tables of the recommendations;
- Supporting recommendations (non-flow related issues that require attention in order that the flow recommendations will achieve their intended objectives).

2. Methods

2.1 The FLOWS method – Stage 1

The recommendations were developed using the framework of the standardised Statewide method for determining environmental water requirements in Victoria, referred to as the FLOWS method (SKM *et al.*, 2002). The major components of FLOWS are shown in Figure 1. Stage 1 of the process, leading to the production of the Issues Paper has been completed (SPDEFTP, 2003).

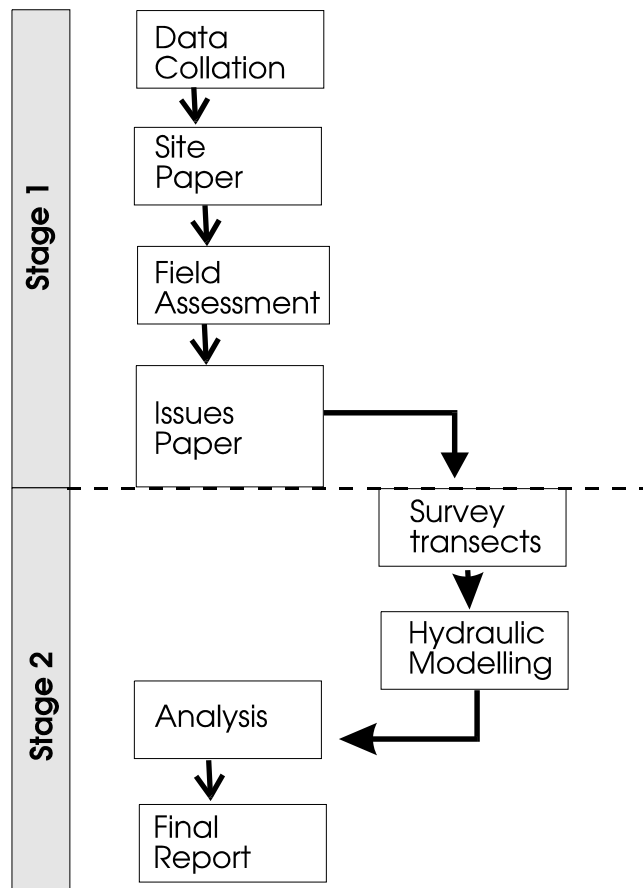


Figure 1. Outline of the steps in the FLOWS method.

In Stage 1, available information on the ecology and hydrology of the study area that was useful to formulate environmental flow recommendations was collected. This information was derived from both published and unpublished sources (including unpublished reports and personal communications from selected individuals).

The available information was used to identify key reaches and sites within the three catchments. Most of the environmental values in the catchments did not show distinct reaches within the system, mainly as a result of inadequate information. However, despite the lack of data, the fish, macroinvertebrates and vegetation information suggested a gradient of conditions, primarily in an upstream-downstream direction.

Only the hydrology and geomorphology data could be interpreted into clear reaches, with 7 reaches identified within the study area:

- Reach 1. Steels Creek headwaters upstream of Jehosaphat Creek;
- Reach 2. Steels Creek from Jehosaphat Creek to Dixons Creek confluence;
- Reach 3. Steels Creek downstream of the junction of Dixons Creek to the Yarra River;
- Reach 4. Dixons Creek headwaters upstream of Brock Spur track at the edge of National Park;
- Reach 5. Dixons Creek from Brock Spur track to the Steels Creek confluence;
- Reach 6. Pauls Creek headwaters in the Toolangi State Forest upstream of “Coornong Vale”.
- Reach 7. Pauls Creek from Toolangi State Forest to the Yarra River.

Of these reaches, only three are discussed further in this report – Reaches 2, 5 and 7. Reaches 1, 4 and 6 are not included they are in natural forest with no or little water resource development. Reach 3 is not included due to the artificial channelised nature of the channel.

Within each of these reaches, a site was selected which was representative of the key features within the reach (Table 1). These representative sites were used in the detailed analyses to assist in quantifying environmental flow recommendations.

Table 1. Location of representative sites in the Steels, Pauls and Dixons Creeks. AMG coordinates are Zone 55.

Reach	Location	AMG
2	Steels Creek upstream of the road crossing at Pinnacle Lane	3568 58378
5	Dixons Creek at G. Miller’s property	3603 58363
7	Pauls Creek at A. McKinlay’s property	3615 58338

A field assessment of the selected sites and other sites in the study area was conducted by the Technical Panel. The field inspection allowed the Technical Panel to assess the suitability of representative sites selected for each reach, identify simple environmental indicators appropriate for each reach, and discuss cross-discipline issues. Within each representative site, the location of transects to be surveyed were marked with pegs. The pegged cross-sections were either hydraulic control points (e.g. logs, riffles, controls), pools (zones of deeper and slower moving water) or cross-sections selected by the Technical Panel as important for ecological interpretation.

Based on all the information gathered, reach-based Environmental Flow Objectives were established for each reach. These objectives are composed of three categories: Biodiversity processes, Ecosystem processes and Flow Components.

- Biodiversity Processes deal with individual biological processes (such as spawning, recruitment, migration, germination, habitat requirements etc) that are required to achieve the overall objective for key listed or threatened flora and fauna within the reach, flora and fauna of local or regional value, or flora and fauna with a strong relationship with flow.
- Ecosystem Processes are processes that occur in an aquatic environment that are not so easily associated with a biodiversity asset to such a specific degree. These are processes with indirect links to the asset (operating through a number of intermediate steps) or those that are known to have more general ecological benefits (such as carbon cycling and the entrainment of leaf litter off the stream banks or floodplain).

- Flow Components identify the important flow components that would need to be present in order to achieve the Biodiversity and Ecosystem processes (that will then achieve the Environmental Flow Objective).

The derivation of the Environmental Flow Objectives for each reach is included in the Issues Paper (SPDEFPTP, 2003), and a summary is presented in Section 3.

2.2 The FLOWS method – Stage 2

2.2.1 Surveys of selected reaches

Cross-sectional surveys at the three sites (Table 1) were undertaken by Earth Tech Engineering Pty Ltd Survey Group. In each reach, the pegged cross-sections identified during the Stage 1 field inspection at each site were surveyed. Cross-section survey points focused on the channel detail, with fewer points on the floodplain.

2.2.2 Hydraulic Modelling

Formulation of the Model

Hydraulic modelling of the sites was undertaken using the one-dimensional steady state backwater analysis model HEC RAS. The survey data for each site were input into the Digital Terrain Model 12D. This package allows direct transfer of data from the survey total station, into 12D, and a HEC RAS hydraulic model created through the 12D package.

Manning's n (a measure of channel roughness) is one of the most important interpretive components of the hydraulic modelling. The appropriate Manning's n for each part of each cross-section was identified through observations of the reach during the field inspection, and identification of reach variability from photographs.

Normal depth was used as the downstream boundary condition, with a slope determined by a combination of the water surface level and the channel invert level, particularly in the lower reaches. The use of this boundary condition allows for adjustment of flows without a corresponding adjustment of boundary condition.

Outputs

The key output from the modelling is a graphic presentation of each transect (see Figure 2). In these, the black line (“Ground” in the legend) represents the ground surface, reflecting the channel shape at the cross-section. 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 outputs used from the model included the flows (ultimately expressed in ML/d) required to cover the stream bed to a certain depth, or inundate identified channel units such as benches, or for fish passage flows (as specified in the Issues Paper and later analysis).

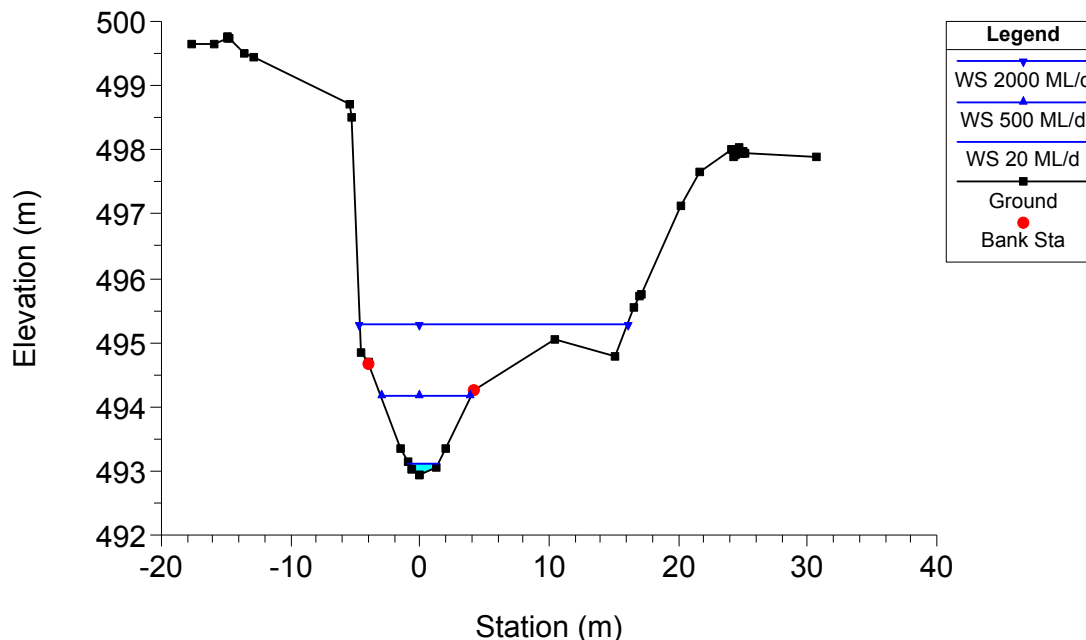


Figure 2. Example cross-section output from the hydraulic model in Steels Creek at 3 different flows.

2.2.3 Analysis

Final environmental flow recommendations for the Steels, Pauls and Dixons Creeks reaches were prepared at a workshop held at the Arthur Rylah Institute for Environmental Research on Monday 17 March 2003. The Technical Panel worked through the process of determining flow recommendations on a reach by reach basis.

Initially, the basic ecological conditions of the reach and the previously determined ecological objectives (from the Issues Paper) were summarised and reviewed. Photos and field notes taken during the field inspection and the survey were examined, and transects constructed by the hydraulic model were viewed to identify key environmental features of the reach.

For 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 suitable flow recommendation was derived by the Technical Panel using a number of analysis tools. These included:

- Criteria or definitions for each of the flow components (Table 2), either from the FLOWS method or developed by the Technical Panel;
- The hydraulic model developed for each reach;
- Drawings and notes taken during the field inspection; and
- Photos taken during the field inspection, and those taken of each transect during the survey.

Table 2. FLOWS method flow components and definitions for use in environmental flow determinations.

Flow component	FLOWS description	Technical Panel criteria
Cease-to-flow	No discernible flow in the river, or no measurable flow recorded at a gauge	A flow of 0.1 ML/d was selected by the Technical Panel as effectively not flowing from an ecological perspective.
Low Flows	Flow that generally provides a continuous flow through the channel	The Technical Panel generally used habitat characteristics (e.g. percent area with a minimum depth) as a low flow measure.
Low Flow Freshes	Small and short duration peak flow events that exceed the baseflow and last for at least several days. Usually summer or spring in Victoria	A flow that exceeds the median flow for the period defined as the Low Flow Season. Also defined as the flow that provided temporary fish passage where appropriate, or suitable stream velocities and power.
High Baseflow	Persistent increases in the seasonal baseflow that remain within the channel	The Technical Panel used either fish passage requirements, or inundation of low in-channel benches as morphological indicators.
High Flow Freshes	Small and short duration peak flow events that exceed the baseflow and last for at least several days.	A flow that exceeds the median flow for the period defined as the High Flow Season or Transitional Flow Seasons. Also defined as the flow that inundated in-channel benches as morphological indicators
Bankfull flow	Completely fill the channel, with little flow spilling onto the floodplain	Geomorphically defined.
Overbank flows	These flows are greater than bankfull and result in surface flow on the floodplain habitats	Geomorphically defined.

Primarily, the hydraulic model was used interactively to identify, represent and visually interpret these flow criteria. For example, to determine flow recommendations for fish passage, a variety of flows were entered into the hydraulic model and adjusted until a flow providing appropriate water depth for fish was obtained. Similarly for bench inundation, flows were entered and adjusted until a particular bench or number of benches identified from the transects or photos were inundated.

Due to uncertainties in the flow data, recommendations for frequency and duration of events (e.g. freshes, bankfull) could not be established. As new, more reliable data become available, frequency and duration recommendations will be developed, based on the natural frequency and duration. The hydrologic program GetSpells will be used to examine the characteristics of particular flows under natural conditions. The recommended frequency and duration will be chosen from within the range of natural conditions (usually the median or modal natural annual frequency and duration).

3. Environmental Flow Objectives Summary

A summary list of all study area Environmental Flow Objectives is presented in Table 3. Due to either incomplete environmental data for some reaches, it was concluded that the species composition of major biota is probably similar in the three reaches, so the same objectives apply to each reach. While other fish species are likely to be present in the three creeks, only five have been included as representatives of certain types of fish guilds (Mountain galaxias, Flatheaded gudgeon and Southern pygmy perch as small non-migratory species, River blackfish as large non-migratory species, and Common galaxias as small migratory species). It is believed that environmental flow recommendations for these taxa should also be adequate for any other fish species that naturally occur in the catchments.

Table 3. Environmental Flow Objectives in the three reaches of Steels, Pauls and Dixons Creeks.

<p>Reach 2 – Steels Creek upstream of Dixons Creek</p> <p>Reach 5 – Dixons Creek upstream of Steels Creek</p> <p>Reach 7 – Pauls Creek</p>
<p>Summary of Environmental Flow Objectives</p>
<ul style="list-style-type: none"> • Maintain or restore self-sustaining populations of Mountain galaxias, Flatheaded gudgeon and Southern pygmy perch. • Maintain or restore self-sustaining populations of River blackfish. • Maintain or restore self-sustaining populations of Common galaxias. • Maintain or restore natural invertebrate community (O/E Score). • Maintain or restore in-stream vegetation community. • Rehabilitate “Riparian Forest” EVC bench and bank vegetation community. • Maintain geomorphic river and channel form.

For each objective, a number of flow-related processes were identified that would contribute to achieving these objectives (Table 4). These consisted of biological processes specific to a particular taxon or community (e.g. spawning triggers for Common galaxias), and broader ecological processes that relate to some or all taxa or communities (e.g. stream substrate condition, low flow water quality), or have indirect links with the biodiversity (carbon cycling).

The flow component from Table 2 that has the most influence on the process was identified, along with a hydraulic surrogate that could be used to evaluate the flow rate for that component (e.g. a specific depth criteria for habitat availability, such as 0.4 m depth representing suitable conditions for River blackfish). These criteria were obtained from published information, from other FLOWS or environmental flow studies that dealt with similar environmental assets, or from expert opinion in the Technical Panel.

Table 4. Flow-related processes and flow components (with hydraulic surrogates) and timings for each objective.

Objective	No.	Flow Process	Draft Flow Objective	
			Flow Component	Timing
Biodiversity Processes				
Maintain or Restore self-sustaining populations of Mountain galaxias, Flatheaded gudgeon, Southern pygmy perch	1a	Habitat availability	Low Flow and High Baseflow (depth >0.2m)	All year
	1b	Localised fish movement between habitats	Low Flow, High Baseflow and/or Freshes (>0.12 m over shallowest point)	Anytime, but especially August to September
Maintain or Restore self-sustaining populations of River blackfish	2a	Habitat availability	Low Flow and High Baseflow (pool >0.4m)	All year
	2b	Localised fish movement leading up to breeding	High Baseflow (>0.2 m over shallowest point)	Spring
Maintain or Restore self-sustaining populations of Common galaxias	3a	Habitat availability	Low Flow and High Baseflow (depth >0.2m)	All year
	3b	Localised fish movement between habitats	Low Flow, High Baseflow and/or Freshes (>0.12 m over shallowest point)	Anytime, but especially Low Flow Season
	3c	Spawning trigger and migration (downstream spawning migration by adults in Autumn, juvenile upstream migration in spring-summer)	Low Flow Fresh, High Baseflow and Freshes (>0.12 m over shallowest point)	Autumn Spring/early Summer
Maintain or restore macroinvertebrate community	4	Habitat availability	Low Flow and High Baseflow (depth >0.1m)	All year
Restore or maintain in-stream vegetation	5	Habitat availability	Low Flow and High Baseflow (depth <0.3m)	All year
Maintain/restore Riparian Forest vegetation community and structure, with zonation up the bank	6a	Habitat inundation – provision of moisture	High Baseflow, High flow Fresh	High Flow Season
	6b	Habitat inundation – variability to provide zonation	High flow variability (High Flow Freshes to Overbank Flow)	High Flow Season
	6c	Habitat regeneration - deposition of sediments	High Flow Freshes to Overbank Flow	High Flow Season
	6d	Habitat disturbance - bank/bench inundation to provide regeneration niches	Overbank Flow	High Flow Season
Ecosystem Processes				
Maintain litter/carbon cycling inputs to river	7a	Bank/bench inundation to provide inputs of dissolved and/or fine organic matter	High Flow Freshes	Autumn to Spring
	7b	Periodic inundation of banks, occasionally with power to entrain woody debris	High Flow Freshes to Overbank Flow	High Flow Season
Maintain stream substrate condition	8a	Substrate scour to remove accumulations of fine sediment	Freshes	Any time
	8b	Scour biofilms	High Flow Freshes	High Flow Season
Improve water quality	9	Re-filling and flushing of stagnant pools	Low Flow Freshes	Low Flow Season
Maintain channel form diversity	10	Disturbance	High Flow Freshes to Overbank Flow	Any time

4. Environmental Flow Recommendations

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

- A Summary of the Reach Condition. These are a very brief summary of the geomorphology, macroinvertebrate, fish and vegetation condition in the reach. These are taken from information presented in the Issues Paper (SPDEFTP, 2003).
- The Flow Recommendations. A discussion and justification of the various flows chosen for recommendation. A number of cross-section plots are presented for each reach with the flows recommended shown. These demonstrate where each flow would be expected to occur in the channel cross-section.
- Summary Tables. The recommendations are presented in the FLOWS format which identifies the various flow processes from Table 4 associated with each recommendation. Additionally, a seasonal table format developed by the Loddon River Environmental Flows Scientific Panel (LREFSP, 2002) is given that presents the recommendations in a more easily visualised manner.
- Supporting Recommendations. These indicate non-flow related issues that require attention in order that the flow recommendations will achieve their intended objectives.

Flow recommendations are made for different flow seasons during the year. From the Issues Paper (SPDEFTP, 2003), the predicted seasonality of the natural flow regime is shown in Table 5.

Table 5. Seasonality of flows adopted for the Steels, Pauls and Dixons Creek catchments.

Season	Months
Low Flow Season	December to April
Transitional: Low to High	May to June
High Flow Season	July to October
Transitional: High to Low	November

4.1 Reach 2 – Steels Creek: Jehosaphat Creek to Dixons Creek

4.1.1 Reach Summary

A summary of the conditions in Reach 2 is shown in Table 6.

Table 6. Summary of environmental conditions in Steels Creek upstream of Dixons Creek.

Aspect	Current condition
Hydrology	<ul style="list-style-type: none"> Unknown.
Geomorphology	<ul style="list-style-type: none"> Partially confined to unconfined valley setting. Historically swampy floodplain, (numerous floodplain paleo-channels). Now deeply incised stream channel. Relatively stable in upper part, less stable in lower sections. Bedrock controls form intermittent rock riffles.
Habitat	<ul style="list-style-type: none"> Pools separated by sections of runs and faster riffles. Bed material mainly clay to sand, pockets of cobbles. Deep pools are significant features.
Fish	<ul style="list-style-type: none"> Very limited data on fish communities available. 3 native species recorded - Short finned eel, Common galaxias and Southern pygmy perch. Up to ten species potentially present - Common galaxias, Broad finned galaxias, Spotted galaxias, Mountain galaxias, Southern pygmy perch, Flatheaded gudgeon, River blackfish, Short-finned eel, Short-headed lamprey and Pouched lamprey
Macroinvertebrates	<ul style="list-style-type: none"> None of the sites sampled met all of the EPA ecological criteria. However, data suggests typical ephemeral flow fauna.
Vegetation	<ul style="list-style-type: none"> Historically “Riparian Forest” (EVC 18) mid-slope riparian vegetation and “Swampy Riparian Woodland” (EVC 83) present on lowland floodplain. Some remnant Riparian Forest remains, but composition now severely degraded, particularly among the ground layer. No information on in-stream vegetation, apart from field observations.

4.1.2 Flow Recommendations

Cease-to-Flow and Low Flows

In Steels Creek, cease-to-flows are a natural component of the flow regime. During these periods, habitat is limited to remnant pools, as shallow areas such as riffles dry out. As the cease-to-flow continues, the water level in the pools will drop due to evaporation and seepage, and water quality will decline. This can lead to periods of physiological stress for the in-stream biota. Only when flows begin again will the pools refill and this stress be relieved. In addition, shallow areas become inundated, allowing for the growth of shallow-water macroinvertebrates and plants. Fish that remain in pools during cease-to-flows can then move out of the pools and feed, regaining condition.

The low flow periods between cease-to-flows can therefore be seen as a period of recovery of the flora and fauna. Therefore, the objective of a cease-to-flow/low flow recommendation is to insure that the stress of cease-to-flow periods is not increased over natural levels, and that the recovery during low flows is as substantial as possible in order for the biota to survive subsequent cease-to-divert periods.

Environmental flow recommendations for cease-to-flow and low flows in unregulated systems (where management of diversions is the only option to deliver specific flows) can be specified as a single Cease-to-Divert flow. This is a flow below which diversions should not occur. The rationale for a Cease-to-Divert flow is that at the point where diversions begin, there is sufficient habitat available through the majority of the site to ensure survival and recovery of aquatic biota during the period of diversions. Of course, when naturally lower flows occur, this habitat may not be available, but the key criteria is that the probability of survival and recovery is maximised during periods of diversion.

Figure 3 shows the long profile of the Steels Creek reach with a flow of 0.1 ML/d (deemed by the Technical Panel as a surrogate for zero flows - Table 2). This represents the situation at the start of a cease-to-flow event. As can be seen, even at zero flow, there is considerable deep water habitat available within the reach. Maximum depths of 1.5 m would be found in the upstream pool (right of Figure 3 and Figure 4), and 1.3 m in downstream pool (left of Figure 3 and Figure 4).

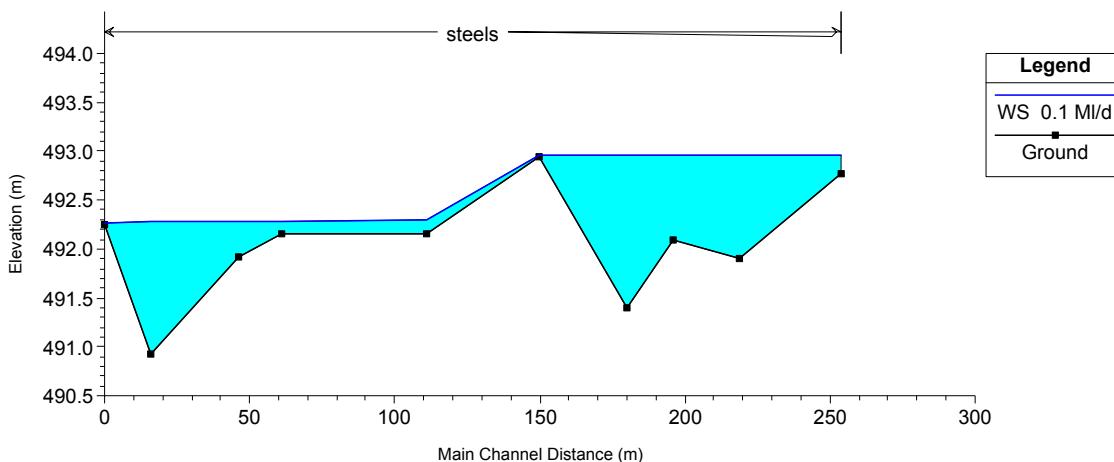


Figure 3. Long profile thalweg of the Steels Creek reach at zero flow.

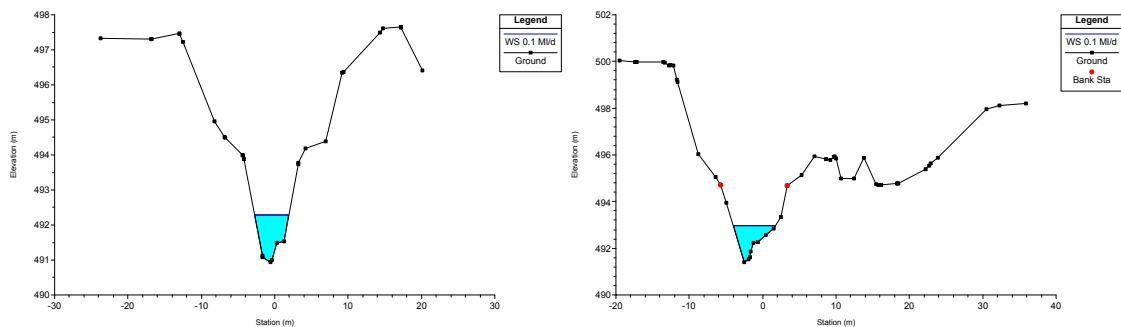


Figure 4. Water surface at zero flow in pools at the downstream end (left) and upstream end (right) of the reach.

In this reach, the criteria chosen to maximise the recovery of flora and fauna between cease-to-flows is to provide adequate habitat in the shallow areas outside of the deeper pools (particularly in the long run between 50-100 m main channel distance in Figure 3). When flowing, this section will be a high zone of macroinvertebrate production with rapid in-stream vegetation growth. Allowing fish to access this part of the reach will provide them with an abundant food source and rapid recovery from any physiological stress.

Of the fish species present (or potentially present - Table 6), the majority are small-bodied. It is unlikely that River blackfish (the only larger-bodied species) will venture long distances into shallow

run reaches, so the objective is to provide adequate areas of the run with depths greater than 0.2 m and shallower than 0.3 m (the hydraulic surrogates for small-bodied fish and in-stream vegetation).

The two transects in the long run are shown in Figure 5, with the low-flow channel circled. A detail of the low-flow channel is shown in Figure 6, with flows of 2, 5, 10 and 20 ML/d.

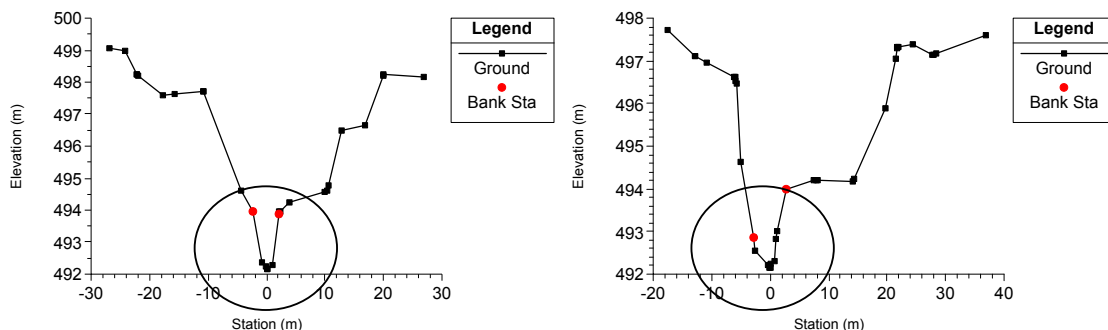


Figure 5. Two transects in the long run in Steels Creek. The low-flow channels in each transect are circled.

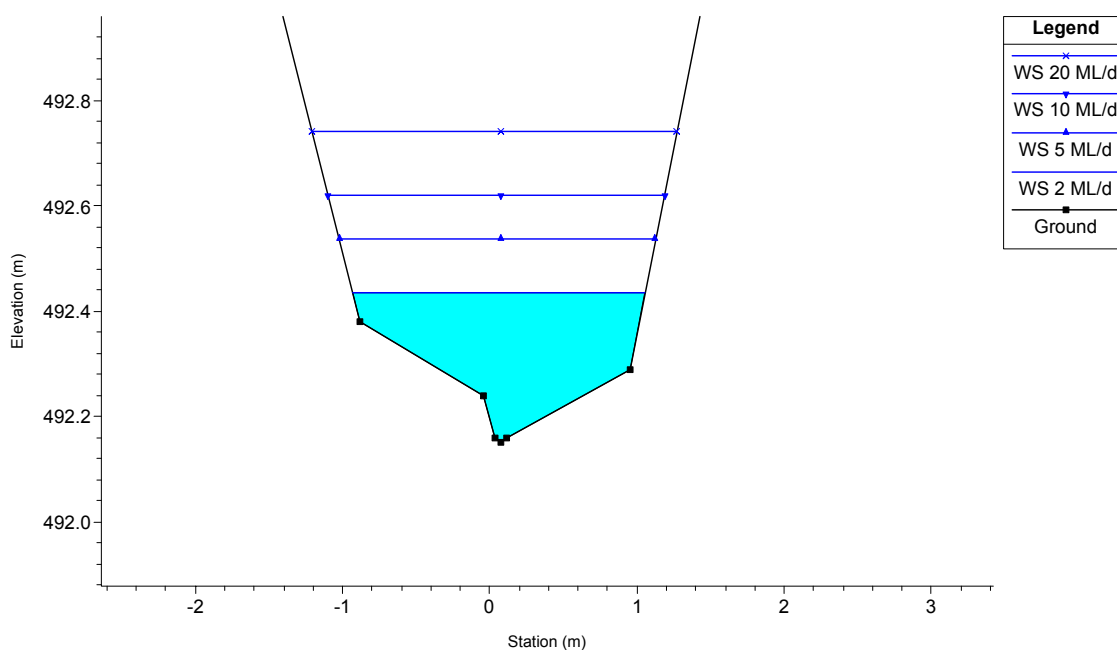


Figure 6. Low flow channel detail (right hand transect from Figure 5) showing flows at 2, 5, 10 and 20 ML/d.

Due to the steep-sided nature of the low-flow channel, the width of the water surface does not vary much between the 4 flows (Table 7). At a flow of 20 ML/d, a large proportion of the wetted low-flow channel in Figure 6 has a depth of greater than 0.2 m (87%). But similar amounts of habitat also occur at flows of 10 and 5 ML/d (85 and 76% respectively). At lower flows, this percentage drops rapidly with only 32% available habitat at 2 ML/d.

But at the higher flow, very little of the channel (20% - Table 7) has a depth less than 0.3 m, suitable for the production of in-stream vegetation. More habitat with this depth criteria are available at 10 and 5 ML/d respectively.

Table 7. Proportion of the low-flow channel in Figure 6 with depths greater than 0.2m and less than 0.3 m.

Flow (ML/d)	Surface water width (m)	Width (m) with depth >0.2 m	% width with depth >0.2 m	% width with depth <0.3 m
20	2.48	2.16	87	20
10	2.28	1.94	85	57
5	2.15	1.63	76	69
2	1.98	0.65	32	100

A cease-to-divert flow of 5 ML/d would seem to represent a good compromise between maintaining adequate depth for small bodied fish and shallow water for the production of in-stream vegetation in runs outside of deep pools in Steels Creek. Thus, during the Low Flow Season (December to April) the recommended Cease-to-Divert flow is 5 ML/d.

Cease-to-Divert flow: 5 ML/d, December to April
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Low Flow Freshes

Low Flow Freshes (short pulses of higher flow) have a number of functions (Table 4). Primarily they refresh water quality in pools during the Low Flow Season, and flush any deposited sediment from habitat substrates. Additionally, Low Flow Freshes also allow recolonisation of these areas in cases where the Cease-to-Divert flow does not allow fish passage. During cease-to-flows, there is the possibility that some isolated pools within the reach will dry completely (depending on the length of the cease-to-flow). In these cases, fish using these refuges may be eliminated from parts of the reach. Low Flow Freshes can allow fish to redistribute themselves through the system.

With a Cease-to-Divert flow of 5 ML/d, the maximum depth at the shallowest point in the reach (at 150 m main channel distance in Figure 3) is less than 0.1 m. This means that the flowing areas of the reach are still effectively isolated during low flows, as depths are insufficient for the effective passage of fish between pools. To enable the recolonisation of any pools where fish have been eliminated, freshes that allow occasional fish passage need to occur during the Low Flow Season. In addition, Low Flow Freshes provide attraction flows and suitable depths for juvenile diadromous fish (eg. Common galaxias), allowing these fish the opportunity to migrate upstream and colonise the creeks.

Again, River blackfish are unlikely to move significant distances over this period, so the criteria selected was for the provision of fish passage for small-bodied fish such as galaxiids (a depth >0.12 m over the shallowest point - Table 4) A depth of 0.12 in the shallowest reach is just achieved at 10 ML/d – however, this is only at the deepest point and the rest of the transect is shallower than this. With an arbitrary criteria that at least 25% of the available channel width should be available for passage, a suitable flow to provide this is 15 ML/d (Figure 7). At this flow, the average channel velocity in this transect is 0.9 m/sec, suitable for movement of fish over the shallowest point¹.

The flow of 15 ML/d produces average water velocities between 0.03 and 0.38 m/sec in all the transects (apart from the shallowest point). These average velocities should, according to Gordon *et al.* (1992), all move particle sizes of greater than 0.5 mm (fine to medium sand). This suggests the freshes would be suitable to maintain substrate conditions, but would also be sufficient to refresh pool water quality.

¹ Of course, localised fish movement occurs in both directions. Velocity may only be an issue for fish moving upstream.

Thus, the Low Flow Fresh recommendation over the Low Flow Season is for regular flows greater than 15 ML/d. Due to uncertainties in the available flow data, recommended frequencies and durations for such flows cannot be recommended at this stage.

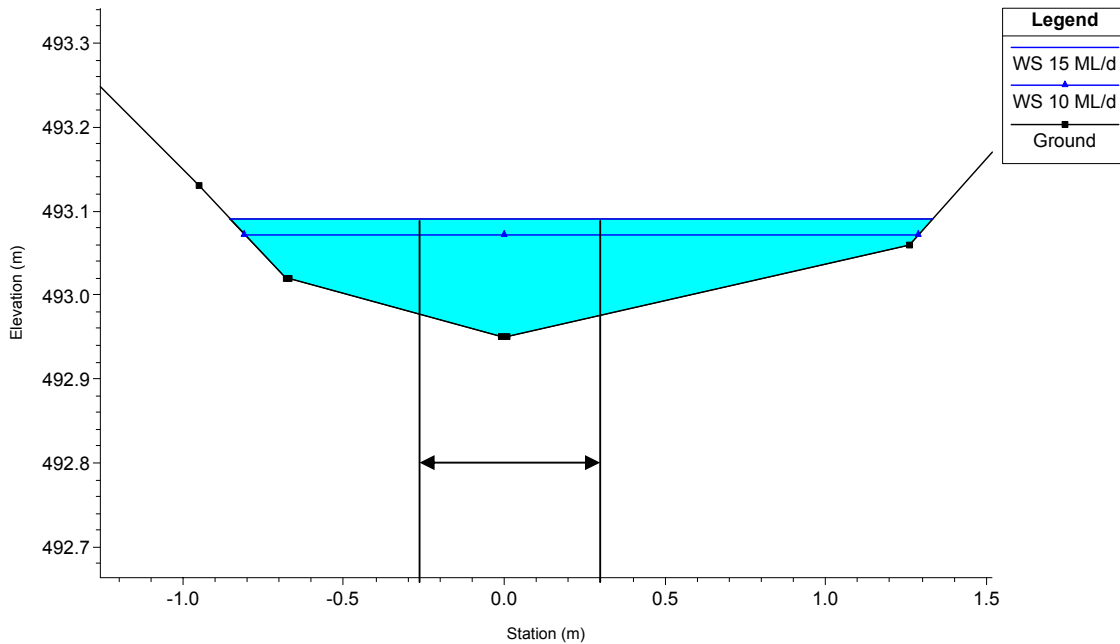


Figure 7. Shallowest point in the reach with a flow of 10 and 15 ML/d. The flowing water between the two vertical lines is suitable for small-bodied fish passage at 15 ML/d.

Low Flow Fresh: Flows greater than 15 ML/d, December to April.

The intent of a fresh recommendation in an unregulated system is that they occur as natural flows, related to rainfall events. In unregulated systems like Steels Creek, freshes cannot be delivered by releasing water from a storage, so the delivery of the freshes at the recommended frequency (to be established) must be through the management of diversions. Therefore, diversions should be managed to ensure that flows of at least 15ML/day can occur between December and April. This could be done, for example, by restricting diversions during particular fresh events (until the flow exceeds, in this case, 15 ML/d), or through limiting the overall diversion rates in the catchment, so that a sufficient proportion of natural flows pass to ensure that the recommendation is met.

High Baseflow

The natural increase in flows that occur in the Transitional Flow Season and early High Flow Season (possibly including May-July in Steels Creek, depending on the natural flow data) is a trigger for a number of ecological events, primarily the migration of Common galaxias to the estuary to breed. Allowing for this migration requires a higher Cease-to-Divert flow in May-July than the 5 ML/d recommended for December to April (which does not provide conditions for effective fish passage through the reach). A suitable Cease-to-Divert flow in May-July would be 15 ML/d which would provide permanent fish passage through the reach (see Figure 7).

This Cease-to-Divert flow should be extended for at least the August to October period to allow population mixing of Mountain galaxias, Flatheaded gudgeon and Southern pygmy perch prior to their breeding season.

In the Transitional Flow Season of November, the Cease-to-Divert flow can be reduced to the Low Flow Season value of 5 ML/d. This reduction in the Cease-to-Divert flow allows for simulation of increases in water temperatures that naturally coincides with reductions in flow in the lead up to the Low Flow Season, thereby creating suitable conditions for blackfish spawning.

High Baseflow:	Cease-to-Divert flow 15 ML/d, May to October
	Cease-to-Divert flow 5 ML/d, November

High Flow Freshes

High Flow Freshes are primarily recommended to maintain the bank and bench vegetation, by providing moisture and sediments to the bank and benches within the channel. They also provide natural disturbances, important in maintaining channel form and diversity. High Flow Freshes also contribute to carbon cycling within the stream by moving organic material (both dissolved, and as leaves and twigs) from the benches into the stream. It is important to remember that the benches in this channel act as a surrogate floodplain, as the channel has enlarged in many reaches reducing the frequencies of overbank flows. Floodplain connectivity is reduced, and additionally, much of the natural floodplain has been modified and cleared of native vegetation.

A flow of 700 ML/d begins to inundate the low level benches in the channel (Figure 8 – upper graphs). Flows of 700 ML/d are likely to occur more than once per year, based on the RORB modelling conclusion that the 1 year ARI flow in Steels Creek at Gulf Road is 1,642 ML/d (Craigie and Brizga, 1998).

Benches higher in the channel are inundate at 2,500 ML/d (Figure 8 – lower graphs). These flows are likely to have significant stream power and would both disturb the vegetation on the lower benches and entrain any woody debris on those benches, moving them into the main channel. Flows of 2,500 ML/d are likely to occur about every 2-3 years based on RORB modelling (Craigie and Brizga, 1998).

The levels of High Flow Freshes recommended, as they are based on flows in the current channel structure (which is stable) would appear adequate to maintain the channel form and structure.

The High Flow Freshes of >700 ML/d early in the season would have a benefit as a spawning/migration trigger for Common galaxias, while any that occur later in the season may allow localised movement of River blackfish in the lead up to the breeding season and provide triggers for upstream migration by juvenile Common galaxias and other diadromous fish. The 700 ML/d flows allow River blackfish and Common galaxias passage through the reach (with 67% of the channel width having depth >0.2 m over the shallow point, and average velocity less than 0.9 m/sec).

High Flow Freshes are only recommended for the period May to November. This is because this is primarily when they occur naturally, and when their ecological benefit is maximised. While such flows can occur outside of the May to November period, these should not be included in the record for compliance purposes.

High Flow Freshes:	Flows greater than 700 ML/d, May to November.
	Flows greater than 2,500 ML/d, May to November.

Similar to the Low Flow Freshes, High Flow Freshes are intended to occur as natural flows, related to rainfall events. The delivery of these freshes can only be through the management of diversions, so that after diversions, the intent of the recommendation is that flows greater than 700 and 2,500 ML/d still occur in Steels Creek at the recommended frequency and duration (to be determined). This may be done by, for example, restricting diversions during particular fresh events (until the flow exceeds the recommended level), or through limiting the overall diversion rates in the catchment, so that a sufficient proportion of natural flows pass to ensure that the recommendation is met.

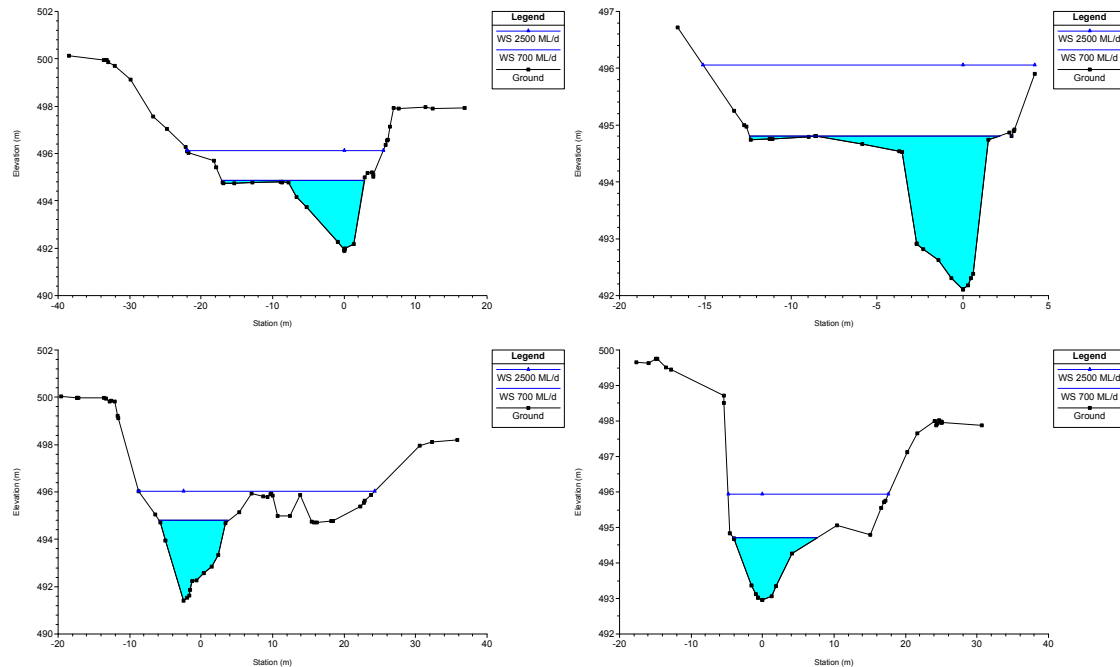


Figure 8. Four transects showing flows at 700 and 2,500 ML/d inundating low in-channel benches and high in-channel benches respectively.

Bankfull and Overbank flow

From the hydraulic model, bankfull flows in the Steels Creek reach are somewhere between 7,000-10,000 ML/d. According to the RORB modelling (Craigie and Brizga, 1998), flows greater than 6,394 ML/d occur only once every 100 years. Hence bankfull flows and overbank flows are now very infrequent (mainly due to the incised nature of the channel).

Recommendations for bankfull and overbank flows are not made for this reach. As the floodplain is modified and cleared of vegetation, the ecological functions of normal floodplains are considered to be performed by the benches within the current channel. Overbank flows are unlikely to have ecological functions in this reach. Indeed, the likely disturbance to the channel structure due to these flows would work against any ecological benefit of the flows. In fact, this is a particularly strong argument that riparian vegetation should be preserved and rehabilitated in the reach. Such high flows, when they do occur, may cause significant damage to the channel. The most likely way to reduce this damage is to have adequate riparian vegetation along the channel.

Bankfull and Overbank flows:	No recommendations
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4.1.3 Summary Tables

Summary tables of the recommendations are presented in the FLOWS format (Table 8) and in a seasonal format (Table 9).

Table 8. Flow recommendations for Reach 2 – Steels Creek from Jehosaphat Creek to Dixons Creek – in the FLOWS format.

River		Steels Creek		Reach	Jehosaphat Creek to Dixons Creek		
Compliance Point		Upstream of Dixons Creek		Gauge No.		No gauge present	
Flow				Rationale			
Season	Magnitude	Frequency Duration	Objectives	Key Evaluation			
Nov-Apr	Cease-to-divert flow 5 ML/d		1a, 2a, 3a, 4, 5	Area of fish habitat > 0.2 m deep			
Dec-Apr	Fresh >15 ML/d		1b, 3b, 8a, 9	Fish passage (>0.12 m)			
May-Oct	Cease-to-divert flow 15 ML/d		1a, 1b, 2a, 3a, 3b, 3c, 4, 5, 8a	Fish passage (>0.12 m)			
May-Nov	Fresh >700 ML/d		2b,3c, 6a, 6b, 6c, 7a, 8b, 10	Low bench inundation			
May-Nov	Fresh Flow >2500 ML/d		6a, 6b, 6c, 6d, 7a, 7b, 8b, 10	High bench inundation			

Table 9. Flow recommendations for Reach 2 – Steels Creek from Jehosaphat Creek to Dixons Creek – in a seasonal format.

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Cease-to-Divert Flow 5 ML/d				Cease-to-Divert Flow 15 ML/d						Cease-to-Divert Flow 5 ML/d	
Low Flow Fresh >15 ML/d				High Flow Fresh >700 ML/d							15 ML/d
				High Flow Fresh >2500 ML/d							

4.1.4 Supporting Recommendations

Spring-fed pools that contain water for long periods of time, were identified in the other two catchments in this study. It is unknown if they occur in Steels Creek. These pools provide secure habitat for fish and other aquatic plants and animals, and should be seen as highly significant refuges. Catchment management activities (e.g. fencing and protection from stock) is important for protecting these significant sites. The distribution of any such pools in Steels Creek is currently unknown, but their distribution should be identified.

In-stream barriers present in the creeks (such as stock crossings, road crossings or small concrete off-take weirs) may prevent movement and migration of fish. These need to be identified and assessed.

The importance of the forested headwaters need to be recognised for their potential impacts on downstream reaches. Protection of these upstream reaches would assist in the delivery of good quality water and act as a potential seed source for riparian and in-stream vegetation.

While no recommendations have been made for bankfull or overbank flows, the rehabilitation of a riparian strip at the top of the channel would assist in protecting the channel from the rare very high flows that will occur in the future. Such high flows may cause significant damage to any unprotected sections at the top of the channel, causing erosion and sedimentation in the channel. Additional leaf material and large woody debris from this riparian zone would add value to in-stream processes (although the major floodplain functions will occur on benches in the channel itself).

4.2 Reach 5 – Dixons Creek: National Park to Steels Creek

4.2.1 Reach Summary

A summary of the conditions in Reach 5 is shown in Table 10.

Table 10. Summary of environmental conditions in Dixons Creek upstream of Steels Creek.

Aspect	Current condition
Hydrology	<ul style="list-style-type: none"> Unknown
Geomorphology	<ul style="list-style-type: none"> Partially confined to unconfined valley setting. Historically swampy floodplain, (numerous floodplain paleo-channels). Now deeply incised stream channel. Unstable sections treated for erosion through the use of rock chutes.
Habitat	<ul style="list-style-type: none"> Pools separated by sections of runs and faster riffles. Bed material mainly clay to sand, pockets of cobbles. Perched water table in some areas lead to permanent pools. These represent significant habitats.
Fish	<ul style="list-style-type: none"> Very limited data on fish communities available. 3 native species recorded – Mountain galaxias, Southern pygmy perch and Flatheaded gudgeon. Anecdotal evidence of River blackfish presence. Up to ten species potentially present - Common galaxias, Broad finned galaxias, Spotted galaxias, Mountain galaxias, Southern pygmy perch, Flatheaded gudgeon, River blackfish, Short-finned eel, Short-headed lamprey and Pouched lamprey
Macroinvertebrates	<ul style="list-style-type: none"> None of the sites sampled met all of the EPA ecological criteria. However, data suggests typical ephemeral flow fauna.
Vegetation	<ul style="list-style-type: none"> Historically “Riparian Forest” (EVC 18) mid-slope riparian vegetation and “Swampy Riparian Woodland” (EVC 83) present on lowland floodplain. Some remnant Riparian Forest remains, but composition now severely degraded, particularly among the ground layer. No information on in-stream vegetation, apart from field observations. Numerous exotic invasive species present. Grazing impacts evident in many locations.

4.2.2 Flow Recommendations

Cease-to-Flow and Low Flows

In Dixons Creek, cease-to-flows are a natural component of the flow regime. During these periods, habitat is limited to remnant pools, as shallow areas such as riffles dry out. As the cease-to-flow continues, the water level in the pools will drop due to evaporation and seepage, and water quality will decline. This can lead to periods of physiological stress for the in-stream biota. Only when flows begin again will the pools refill and this stress be relieved. In addition, shallow areas become inundated, allowing for the growth of shallow-water macroinvertebrates and plants. Fish that remain in pools during cease-to-flows can then move out of the pools and feed, regaining condition.

The low flow periods between cease-to-flows can therefore be seen as a period of recovery of the flora and fauna. Therefore, the objective of a cease-to-flow/low flow recommendation is to insure that the stress of cease-to-flow periods is not increased over natural levels, and that the recovery during low flows is as substantial as possible in order for the biota to survive subsequent cease-to-divert periods.

Environmental flow recommendations for cease-to-flow and low flows in unregulated systems (where management of diversions is the only option to deliver specific flows) can be specified as a single Cease-to-Divert flow. This is a flow below which diversions should not occur. The rationale for a Cease-to-Divert flow is that at the point where diversions begin, there is sufficient habitat available through the majority of the site to ensure survival and recovery of aquatic biota during the period of diversions. Of course, when naturally lower flows occur, this habitat may not be available, but the key criteria is that the probability of survival and recovery is maximised during periods of diversion.

Figure 9 shows the long profile of the Dixons Creek reach with a nominal flow of 0.1 ML/d (zero flow surrogate), representing the situation at the start of a cease-to-flow event. As for Steels Creek, the rationale behind selecting a Cease-to-Divert flow is to maximise the amount of suitable habitat in the reach before diversions are allowed. Unlike Steels Creek, the pools in the reach are generally shallower, with maximum depths of only 30 cm at the deepest point in the representative reach at zero flows (transect at about 150 m main channel distance - Figure 10).

In this case, the objectives of a Cease-to-Divert flow would be to provide habitat for River blackfish in the pool, and for small-bodied fish, macroinvertebrates and in-stream vegetation in areas outside the pool. This differs from Steels Creek in that pools at zero flow had sufficient River blackfish habitat (depths >0.4 m), whereas the Dixons Creek reach has less than adequate River blackfish habitat at zero flows. River blackfish should be considered a significant asset within the reach due to the anecdotal evidence for their presence.

Hence, the criteria for a Cease-to-Divert flow is adequate area with depth greater than 0.4 m in the pool (the hydraulic surrogate for River blackfish), and area with depth greater than 0.2 m and less than 0.3 m outside the pool (hydraulic surrogates for small bodied fish and in-stream vegetation respectively).

A flow of 1 ML/d just provides 0.4 m depth at the deepest point of the pool (Figure 11), but does not provide any area of habitat. Flows between 10-20 ML/d provide more than 50% of the pool width with suitable habitat, suggesting a Cease-to-Divert flow should be between these values. With increasing flows above 20 ML/d, the incremental benefit to blackfish habitat decreases (i.e. while the absolute amount of habitat increases, the proportional amount of habitat added by more flow declines).

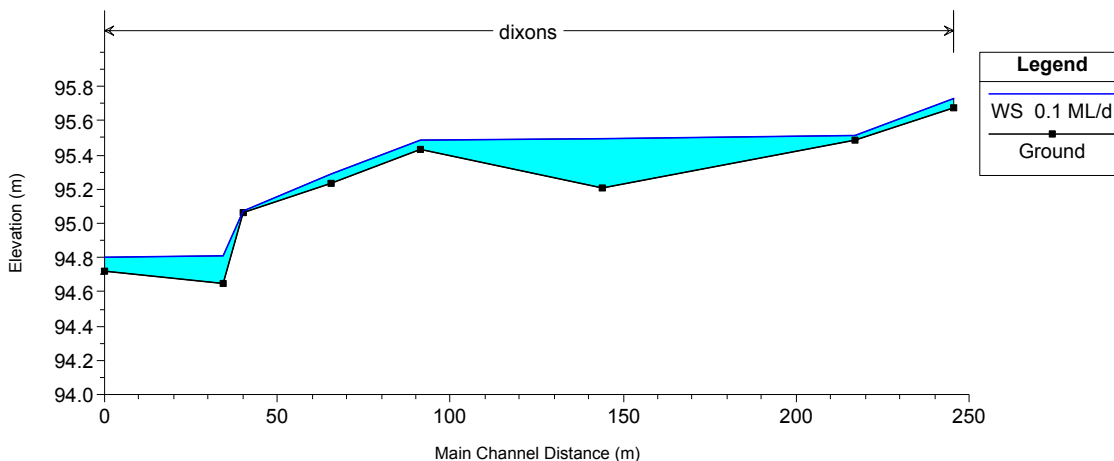


Figure 9. Long profile thalweg of the Dixons Creek reach at zero flow.

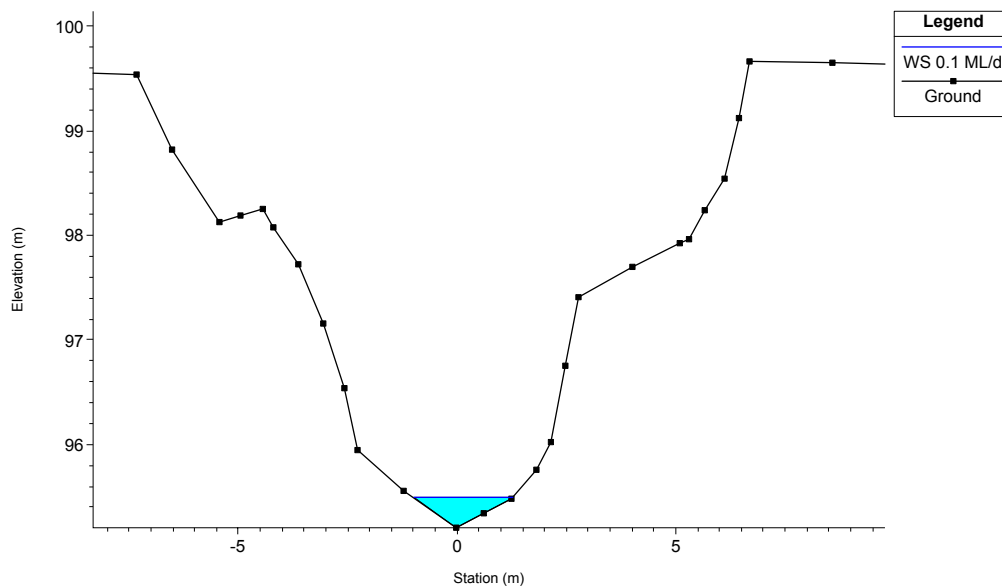


Figure 10. Water surface at zero flow in the main pool in the middle of the Dixons Creek reach.

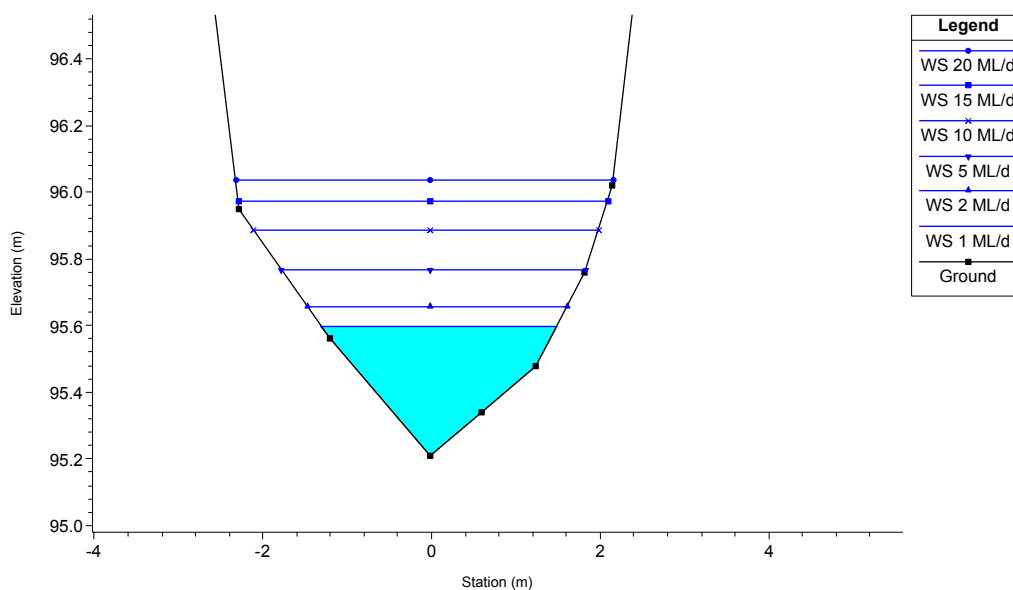


Figure 11. Detail of the pool area with flows between 1 and 20 ML/d.

Table 11. Proportion of pool transect with depths greater than 0.4 m.

Flow (ML/d)	Surface water width (m)	Width (m) of depth >0.4 m	% with depth >0.4 m
2	3.08	0.42	14
5	3.61	1.30	36
10	4.09	2.18	53
15	4.38	2.68	61
20	4.48	2.98	66

Outside of the major pool areas, flows between 10-20 ML/d produce variable amounts of habitat with depths greater than 20 cm, and depths less than 30 cm. In a transect typical of long run habitats (at 220 m main channel distance in Figure 9), flows of 15 and 20 ML/d produced high proportions of habitat deeper than 0.2 m, but with 20 ML/d producing relatively low proportions of habitat shallower than 0.3 m (Figure 12). For this reason, a flow of 15 ML/d as a Cease-to-Divert flow would seem a good compromise in producing the most amount of suitable habitat while diversions are occurring.

Cease-to-Divert flow: 15 ML/d, December to April

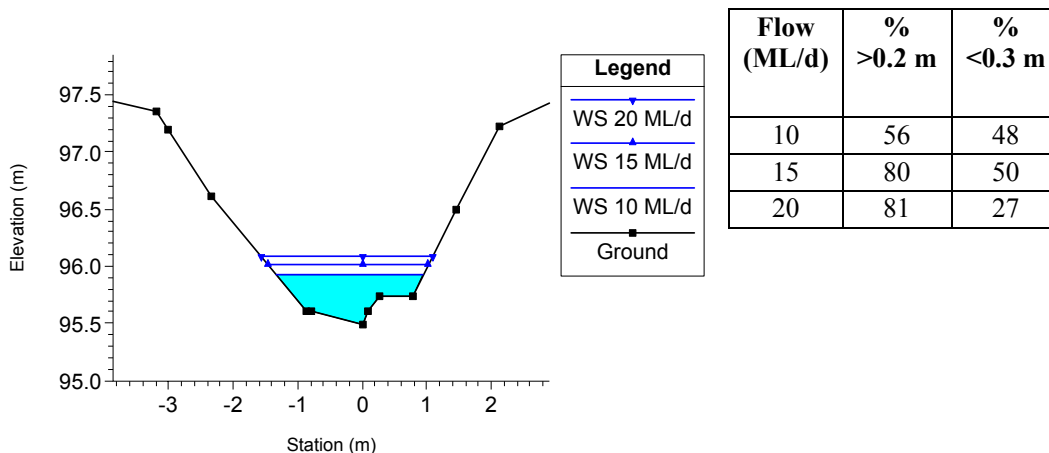


Figure 12. Transect at 220 m main channel distance, with proportions of the cross-section deeper than 0.2 m and shallower than 0.3 m at three flows.

Low Flow Freshes

Low Flow Freshes (short pulses of higher flow) have a number of functions (Table 4). Primarily they refresh water quality in pools during the Low Flow Season, and flush any deposited sediment from habitat substrates. Additionally, Low Flow Freshes also allow recolonisation of these areas in cases where the Cease-to-Divert flow does not allow fish passage. During cease-to-flows, there is the possibility that some isolated pools within the reach will dry completely (depending on the length of the cease-to-flow). In these cases, fish using these refuges may be eliminated from parts of the reach. Low Flow Freshes can allow fish to redistribute themselves through the system.

At the Cease-to-Divert flow of 15 ML/d, there is already adequate provision for fish passage at two shallow or narrow transects (Figure 13), with most of the channel width (50-75%) with depths of greater than 0.12 m. Velocities through these sections at 15 ML/d average 1.1-1.2 m/sec which is adequate for access by small fish.

Average channel velocities in the remainder of the reach outside of the main pool vary from between 0.14-0.27 m/sec at a flow of 15 ML/d, suitable to move fine particles from the stream bed. Average velocity in the pool is 0.1 m/sec, which should be adequate to refresh water quality.

Therefore, there appears to be no justification for recommending specific Low Flow Freshes in this reach. While unusual, this is not unprecedented. In the Lerderderg River, no Low Flow Freshes were recommended as the Cease-to-Divert flow was sufficiently high to achieve all the objectives associated with Low Flow Freshes (LREFTP, 2002).

Low Flow Fresh: No recommendations

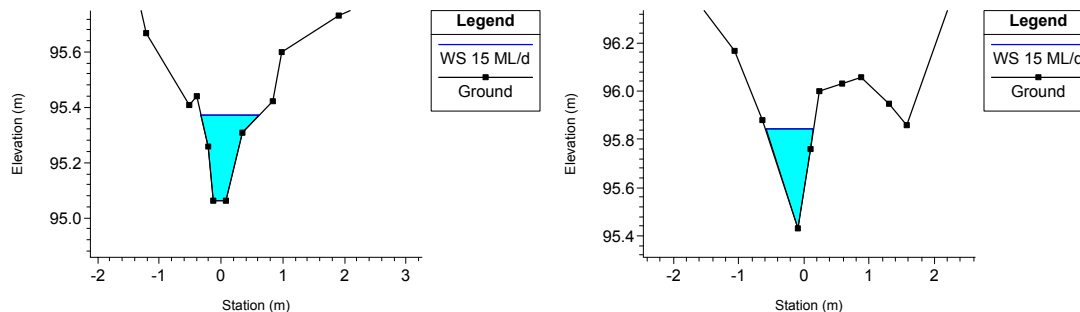


Figure 13. Two shallow transects at 40m (left) and 91 m (right) main channel distance with a flow of 15 ML/d.

High Baseflow

The rationale for a High Baseflow recommendation in Steels Creek was primarily to allow for permanent fish passage for Common galaxias to migrate to the estuary to breed, and for the distribution of other small-bodied fish later in the year. In Dixons Creek, the Cease-to-Divert flow of 15 ML/d over the Low Flow Season allows adequate fish passage for small-bodied fish, and would therefore be a suitable Cease-to-Divert over the higher flow months as well (see Figure 13).

High Baseflow: Cease-to-Divert flow 15 ML/d, May to November

High Flow Freshes

High Flow Freshes are primarily recommended to maintain the bank and bench vegetation, by providing moisture and sediments to the bank and benches within the channel. They also provide natural disturbances, important in maintaining channel form and diversity. High Flow Freshes also contribute to carbon cycling within the stream by moving organic material (both dissolved, and as leaves and twigs) from the benches into the stream. It is important to remember that the benches in this channel act as a surrogate floodplain, as the channel has enlarged in many reaches reducing the frequencies of overbank flows. Floodplain connectivity is reduced, and additionally, much of the natural floodplain has been modified and cleared of native vegetation.

A number of distinct bank forms can be identified in the Dixons Creek reach (Figure 14). These include low-level benches near the base of the channel, mid-level benches or slope changes approximately half-way up the bank, and high-level benches towards the top of the channel. Significant riparian vegetation mainly occurs on the mid and upper benches, while semi aquatic herbs and sedges tend to occur on the lower benches.

Each of these bank forms need to be inundated to maintain the diversity of riparian vegetation forms. Flows of 50, 500 and 1,250 ML/d were determined to adequately inundate the different bench forms (Figure 15, Figure 16).

Frequencies and durations cannot be estimated due to the flow data. However, according to the RORB modelling (IDA, 2000), flows of 778 ML/d had an ARI of 1 year in Dixons Creek, suggesting flows of 50 and 500 ML/d may occur more than once per year. A flow of 1,210 ML/d had an ARI of 2 years, suggesting that the highest recommended flow would occur once every 2 years.

The levels of freshes recommended, as they are based on the current channel structure (which is stable), would appear adequate to maintain this structure.

The High Flow Freshes of >50 or >500 ML/d early in the season would have a benefit as a spawning/migration trigger for Common galaxias, while any that occur later in the season may allow localise movement of River blackfish in the lead up to the breeding season. The 50 ML/d allows blackfish passage through the reach (with 50-60% of the channel width at transects in Figure 13 having depth >0.2 m over the shallow point, and average velocity less than 0.9 m/sec).

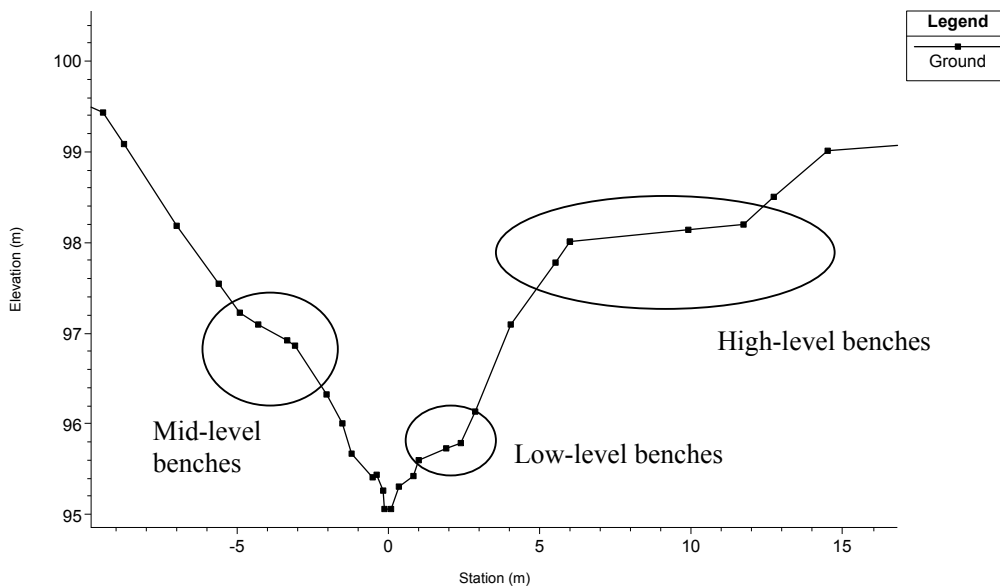


Figure 14. Examples of bench and bank forms in Dixons Creek

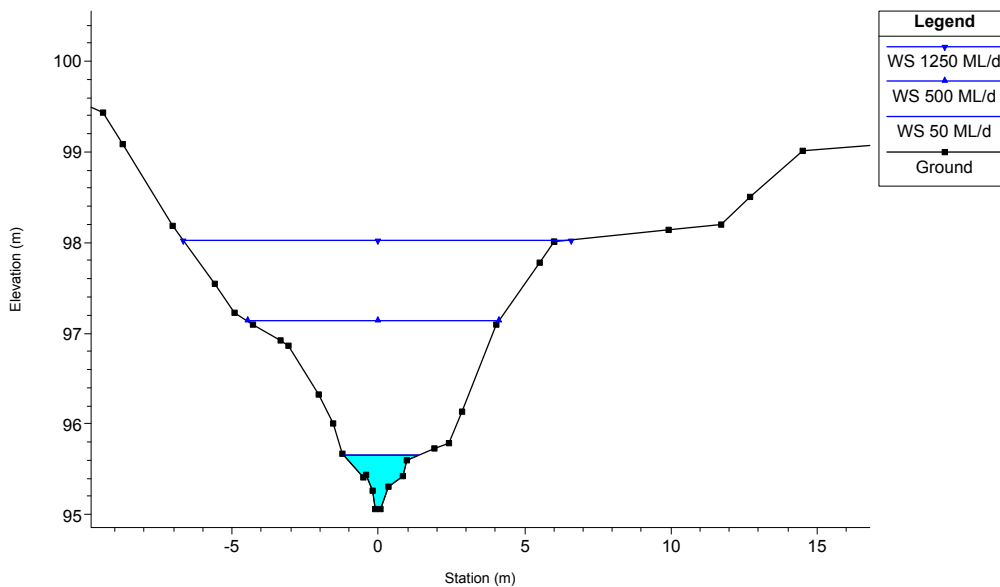


Figure 15. Transect shown in Figure 14 with flows of 50, 500 and 1,250 ML/d

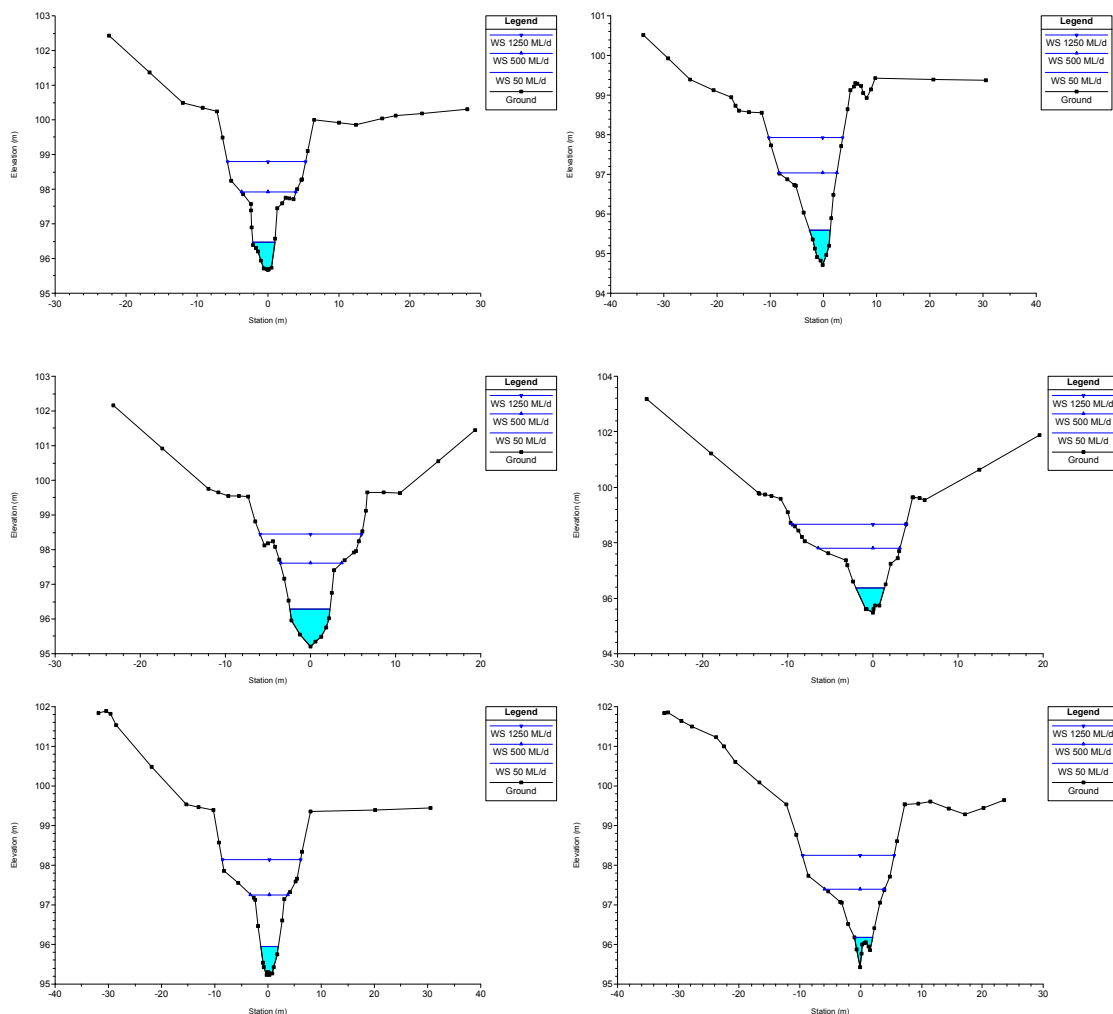


Figure 16. Selected Dixons Creek transects with 50, 500 and 1,250 ML/d flows, showing inundation of different bank forms.

High Flow Freshes are only recommended for the period May to November. This is because this is primarily when they occur naturally (probably), and when their ecological benefit is maximised. While such flows can occur outside of the May to November period, these should not be included in the record for compliance purposes.

High Flow Freshes: Flows greater than 50 ML/d, May to November

Flows greater than 500 ML/d, May to November

Flows greater than 1,250 ML/d, May to November

Similar to the Low Flow Freshes, High Flow Freshes are intended to occur as natural flows, related to rainfall events. The delivery of these freshes can only be through the management of diversions, so that after diversions, flows greater than 50, 500 and 1,250 ML/d still occur in the system at the recommended frequency and duration (to be determined) during May to November. This may be done by, for example, restricting diversions during particular fresh events (until the flow exceeds the recommended level), or through limiting the overall diversion rates in the catchment, so that a sufficient proportion of natural flows pass to ensure that the recommendation is met.

Bankfull and Overbank flow

As for Steels Creek, recommendations for bankfull and overbank flows are not made for this reach. As the floodplain is modified and cleared of vegetation, the ecological functions of normal floodplains are performed by the benches within the current channel. Overbank flows would have no ecological function in this reach. Indeed, the likely disturbance to the channel structure due to these flows would work against any ecological benefit of the flows. In fact, this is a particularly strong argument that riparian vegetation should be preserved and rehabilitated in the reach. Such high flows, when they do occur, may cause significant damage to the channel. The most likely way to reduce this damage is to have adequate riparian vegetation along the channel.

In any case, under current extraction conditions, these very high flow flood events should not be greatly impacted and will naturally occur.

Bankfull and Overbank flows:	No recommendations
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4.2.3 Summary Tables

Summary tables of the recommendations are presented in the FLOWS format (Table 12) and in a seasonal format (Table 13).

Table 12. Flow recommendations for Reach 5 – Dixons Creek from the National Park to Steels Creek – in the FLOWS format.

River	Dixons Creek		Reach	National Park to Steels Creek
Compliance Point	Upstream of Steels Creek		Gauge No.	No gauge present
Flow			Rationale	
Season	Magnitude	Frequency Duration	Objectives	Key Evaluation
All year	Cease-to-divert flow 15 ML/d		1a, 1b, 2a, 3a, 3b, 3c, 4, 5, 8a, 9	Area of fish habitat > 0.2 m deep, Fish passage (>0.12 m)
May-Nov	Fresh >50 ML/d		2b, 3c, 6a, 6b, 6c, 7a, 8b, 10	Low bench inundation
May-Nov	Fresh >500 ML/d		2b,3c, 6a, 6b, 6c, 7a, 7b, 8b, 10	Mid bench inundation
May-Nov	Fresh Flow >1250 ML/d		6a, 6b, 6c, 6d, 7a, 7b, 8b, 10	High bench inundation

Table 13. Flow recommendations for Reach 5 – Dixons Creek from the National Park to Steels Creek – in a seasonal format.

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Cease-to-Divert Flow 15 ML/d											
				High Flow Fresh >50 ML/d							
				High Flow Fresh >500 ML/d							
				High Flow Fresh >1,250 ML/d							

4.2.4 Supporting Recommendations

Spring-fed pools that contain water for long periods of time, were identified in Dixons Creek. These pools provide secure habitat for fish and other aquatic plants and animals, and should be seen as highly significant refuges. Catchment management activities (e.g. fencing and protection from stock) is important for protecting these significant sites. The distribution of any such pools in Dixons Creek is currently unknown, but their distribution should be identified.

In-stream barriers present in the creeks (such as stock crossings, road crossings or small concrete off-take weirs) may prevent movement and migration of fish. These need to be identified and assessed.

The importance of the forested headwaters need to be recognised for their potential impacts on downstream reaches. Protection of these upstream reaches would assist in the delivery of good quality water and act as a potential seed source for riparian and in-stream vegetation.

While no recommendations have been made for bankfull or overbank flows, the rehabilitation and protection of a riparian strip at the top of the channel would assist in protecting the channel from the rare very high flows that will occur in the future. Such high flows may cause significant damage to any unprotected sections at the top of the channel, causing erosion and sedimentation in the channel. Additional leaf material and large woody debris from this riparian zone would add value to in-stream processes (although the major floodplain functions will occur on benches in the channel itself). It is therefore recommended that in conjunction with any flow rehabilitation, the grazing of riparian vegetation be addressed through activities such as riparian fencing and off-stream watering systems.

4.3 Reach 7 – Pauls Creek: State Forest to the Yarra River

4.3.1 Reach Summary

A summary of the conditions in Reach 7 is shown in Table 14.

Table 14. Summary of environmental conditions in Pauls Creek downstream of the State Forest.

Aspect	Current condition
Hydrology	<ul style="list-style-type: none"> Unknown
Geomorphology	<ul style="list-style-type: none"> Deeply incised stream channel. larger capacity upstream than down Bed grade of the lower Pauls Creek is steeper than Steels or Dixons Creeks.
Habitat	<ul style="list-style-type: none"> Pools separated by sections of runs and faster riffles. Bed material mainly clay to sand, pockets of cobbles. Deep pools are the most significant features.
Fish	<ul style="list-style-type: none"> No fish data. Up to ten species potentially present - Common galaxias, Broad finned galaxias, Spotted galaxias, Mountain galaxias, Southern pygmy perch, Flatheaded gudgeon, River blackfish, Short-finned eel, Short-headed lamprey and Pouched lamprey
Macroinvertebrates	<ul style="list-style-type: none"> None of the sites sampled met all of the EPA ecological criteria. However, data suggests typical ephemeral flow fauna.
Vegetation	<ul style="list-style-type: none"> Historically “Riparian Forest” (EVC 18) mid-slope riparian vegetation and “Swampy Riparian Woodland” (EVC 83) present on lowland floodplain. Some remnant Riparian Forest remains, but composition now severely degraded, particularly among the ground layer. No information on in-stream vegetation, apart from field observations.

4.3.2 Flow Recommendations

Cease-to-Divert Flow

In Pauls Creek, cease-to-flows are a natural component of the flow regime. During these periods, habitat is limited to remnant pools, as shallow areas such as riffles dry out. As the cease-to-flow continues, the water level in the pools will drop due to evaporation and seepage, and water quality will decline. This can lead to periods of physiological stress for the in-stream biota. Only when flows begin again will the pools refill and this stress be relieved. In addition, shallow areas become inundated, allowing for the growth of shallow-water macroinvertebrates and plants. Fish that remain in pools during cease-to-flows can then move out of the pools and feed, regaining condition.

The low flow periods between cease-to-flows can therefore be seen as a period of recovery of the flora and fauna. Therefore, the objective of a cease-to-flow/low flow recommendation is to insure that the stress of cease-to-flow periods is not increased over natural levels, and that the recovery during low flows is as substantial as possible in order for the biota to survive subsequent cease-to-divert periods.

Environmental flow recommendations for cease-to-flow and low flows in unregulated systems (where management of diversions is the only option to deliver specific flows) can be specified as a single Cease-to-Divert flow. This is a flow below which diversions should not occur. The rationale for a

Cease-to-Divert flow is that at the point where diversions begin, there is sufficient habitat available through the majority of the site to ensure survival and recovery of aquatic biota during the period of diversions. Of course, when naturally lower flows occur, this habitat may not be available, but the key criteria is that the probability of survival and recovery is maximised during periods of diversion.

Figure 17 shows the long profile of the Pauls Creek reach with a nominal zero flow of 0.1 ML/d, representing the situation at the start of a cease-to-flow event. The reach consist of a fairly shallow pool at the downstream end of the reach (Figure 18) and a fairly uniform channel through the remainder. This pool has a maximum depth of 0.45 m at zero flow, so should represent a refuge for River blackfish during low flows. Therefore, the rationale behind selecting a Cease-to-Divert flow is to maximise the amount of suitable habitat for macroinvertebrates, small-bodied fish and in-stream vegetation in areas outside the pool.

The criteria for a Cease-to-Divert flow is adequate depth greater than 0.2 m and less than 0.3 m (hydraulic surrogates for small-bodied fish and in-stream vegetation respectively) in the deeper parts of the long shallow part of the reach. These hydraulic criteria should also provide adequate habitat for macroinvertebrates. As most of the channel is relatively uniform, the intent is to provide some habitat throughout the reach.

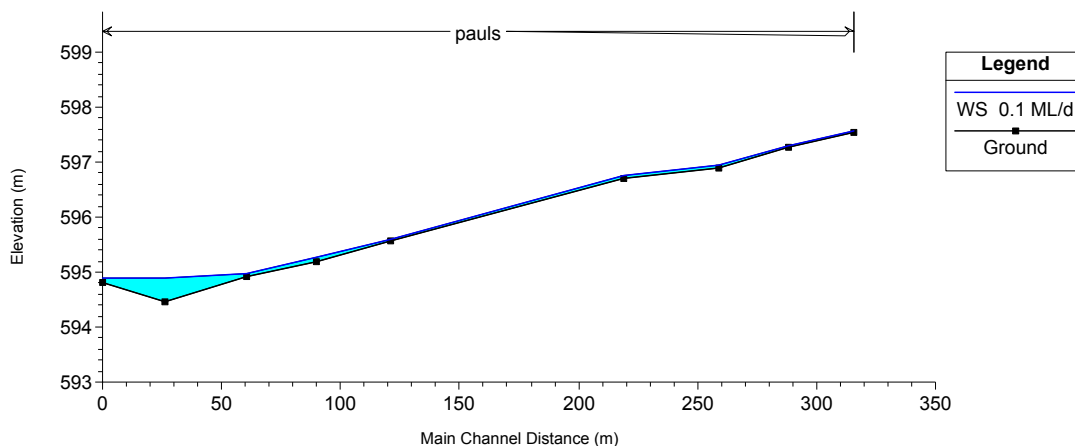


Figure 17. Long thalweg profile of the Pauls Creek reach at zero flow.

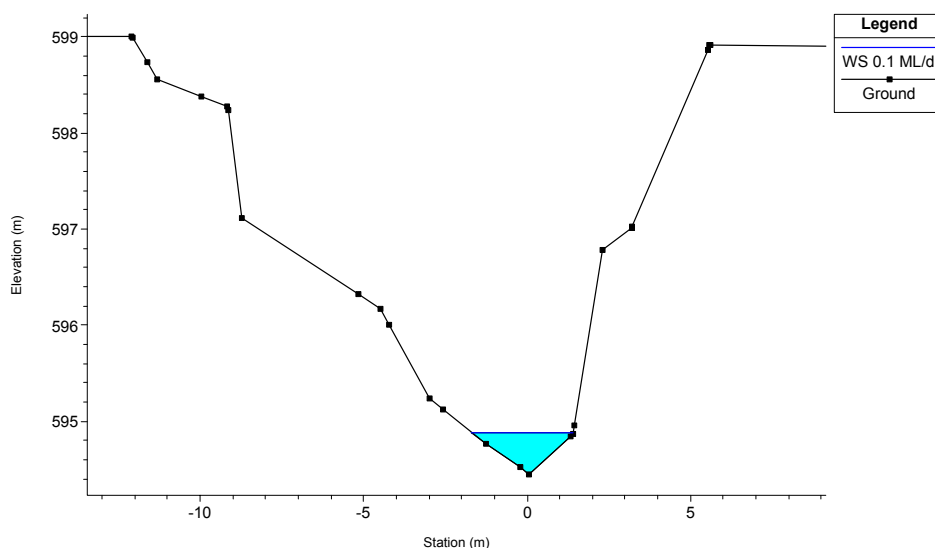


Figure 18. Water surface at zero flow in the main pool at the lower end of the reach.

At flows of 2 and 5 ML/d few of the transects upstream of the main pool have any habitat deeper than 0.2 m (Figure 19). Only at flows greater than 15 ML/d do all transects have at least some habitat suiting that criteria. This varies between 1 and 67% of the available channel width (Table 15).

At 15 ML/d, the majority of available habitat in all reaches is less than 0.3 m depth (Table 15), suggesting that 15 ML/d would be a suitable Cease-to-Divert flow.

Cease-to-Divert flow: 15 ML/d, December to April.

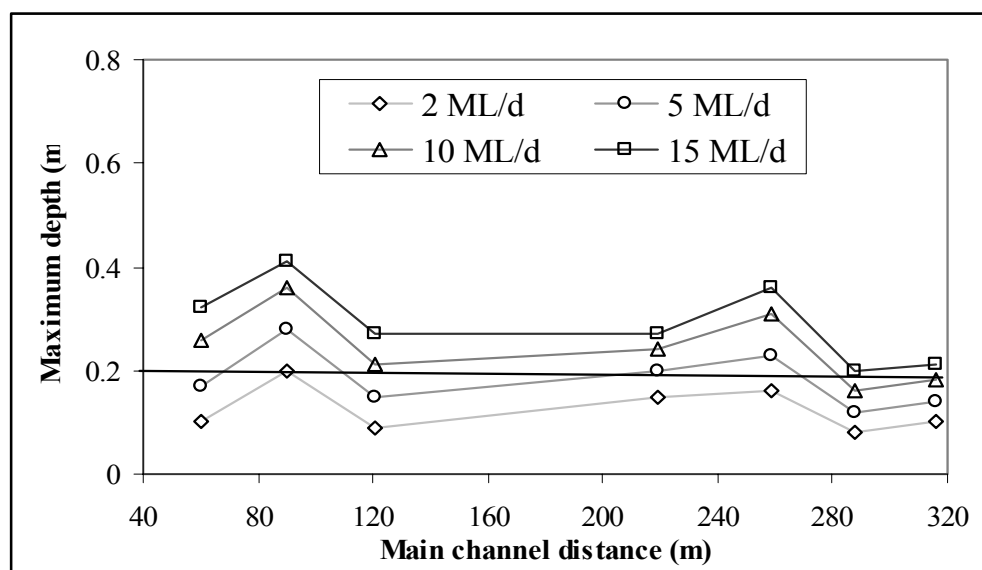


Figure 19. Maximum depth at each transect upstream of the main pool at 4 different flows.

Table 15. Proportion of available channel width with depths greater than 0.2 m, and less than 0.3 m at each transect upstream of the main pool, at 15 ML/d.

Main channel distance	60	90	120	220	260	290	315
% more than 0.2 m	41	67	45	32	50	1	8
% less than 0.3 m	95	60	100	100	77	100	100

Low Flow Freshes

Low Flow Freshes (short pulses of higher flow) have a number of functions (Table 4). Primarily they refresh water quality in pools during the Low Flow Season, and flush any deposited sediment from habitat substrates. Additionally, Low Flow Freshes also allow recolonisation of these areas in cases where the Cease-to-Divert flow does not allow fish passage. During cease-to-flows, there is the possibility that some isolated pools within the reach will dry completely (depending on the length of the cease-to-flow). In these cases, fish using these refuges may be eliminated from parts of the reach. Low Flow Freshes can allow fish to redistribute themselves through the system.

As in Dixons Creek, at the Cease-to-Divert flow of 15 ML/d, there is already adequate provision for fish passage at the shallowest transect (Figure 20), with 52% of the water width with depths of 0.12 m or more.

Channel velocity at transects outside of the pool at 15 ML/d averaged 0.34-0.56 m/sec, clearly adequate to allow fish movement, and also to flush fine sediment from the bed at the Cease-to-Divert

flow. Average velocity in the pool was 0.1 m/sec, again, adequate to refresh the water quality. Therefore, no Low Flow Season freshes are recommended for the reach.

Low Flow Freshes: No recommendations

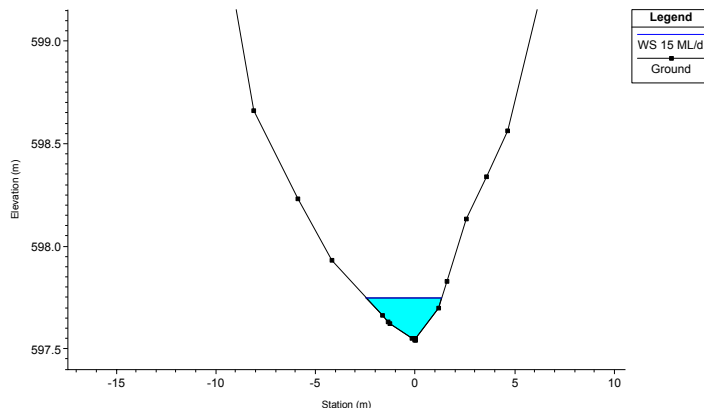


Figure 20. Shallow transect (at 315 m main channel distance) with a flow of 15 ML/d.

High Baseflow

The rationale for a High Baseflow recommendation in Pauls Creek was primarily to allow for permanent fish passage for Common galaxias to migrate to the estuary to breed, and for small-bodied fish movement later in the season. The Cease-to-Divert flow of 15 ML/d over the Low Flow Season allows adequate fish passage for small-bodied fish, and would therefore be a suitable Cease-to-Divert over the higher flow months as well (see Figure 20).

High Baseflow: Cease-to-Divert flow 15 ML/d, May to November

High Flow Freshes

High Flow Freshes are primarily recommended to maintain the bank and bench vegetation, by providing moisture and sediments to the bank and benches within the channel. They also provide natural disturbances, important in maintaining channel form and diversity. High Flow Freshes also contribute to carbon cycling within the stream by moving organic material (both dissolved, and as leaves and twigs) from the benches into the stream. It is important to remember that the benches in this channel act as a surrogate floodplain, as the channel has enlarged in many reaches reducing the frequencies of overbank flows. Floodplain connectivity is reduced, and additionally, much of the natural floodplain has been modified and cleared of native vegetation.

A number of bench types were identified in Pauls Creek (Figure 21). Flows assessed to adequately inundate these benches were assessed as 150 and 520 ML/d (Figure 22).

The High Flow Freshes of >150 ML/d early in the season would have a benefit as a spawning/migration trigger for Common galaxias, while any that occur later in the season may allow localise movement of River blackfish in the lead up to the breeding season. The 150 ML/d allows blackfish passage through the reach (with 72% of the channel width having depth >0.2 m over the shallow point, and average velocity less than 0.8 m/sec).

The levels of freshes recommended, as they are based on the current channel structure (which is stable) would appear adequate to maintain this structure.

As no RORB modelling has been conducted on Pauls Creek, it is impossible to say how frequently these flow may occur. They should therefore be seen as preliminary recommendations to be re-assessed once adequate flow data are available.

High Flow Freshes: Flows greater than 150 ML/d, May to November
Flows greater than 520 ML/d, May to November

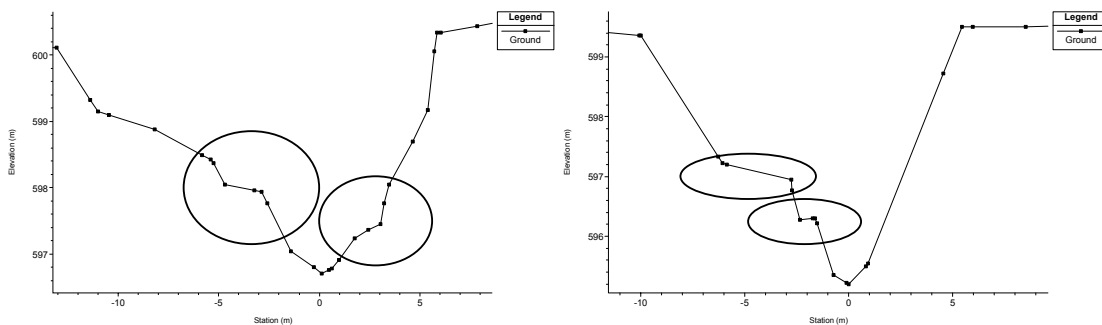


Figure 21. Examples of benches identified in Pauls Creek.

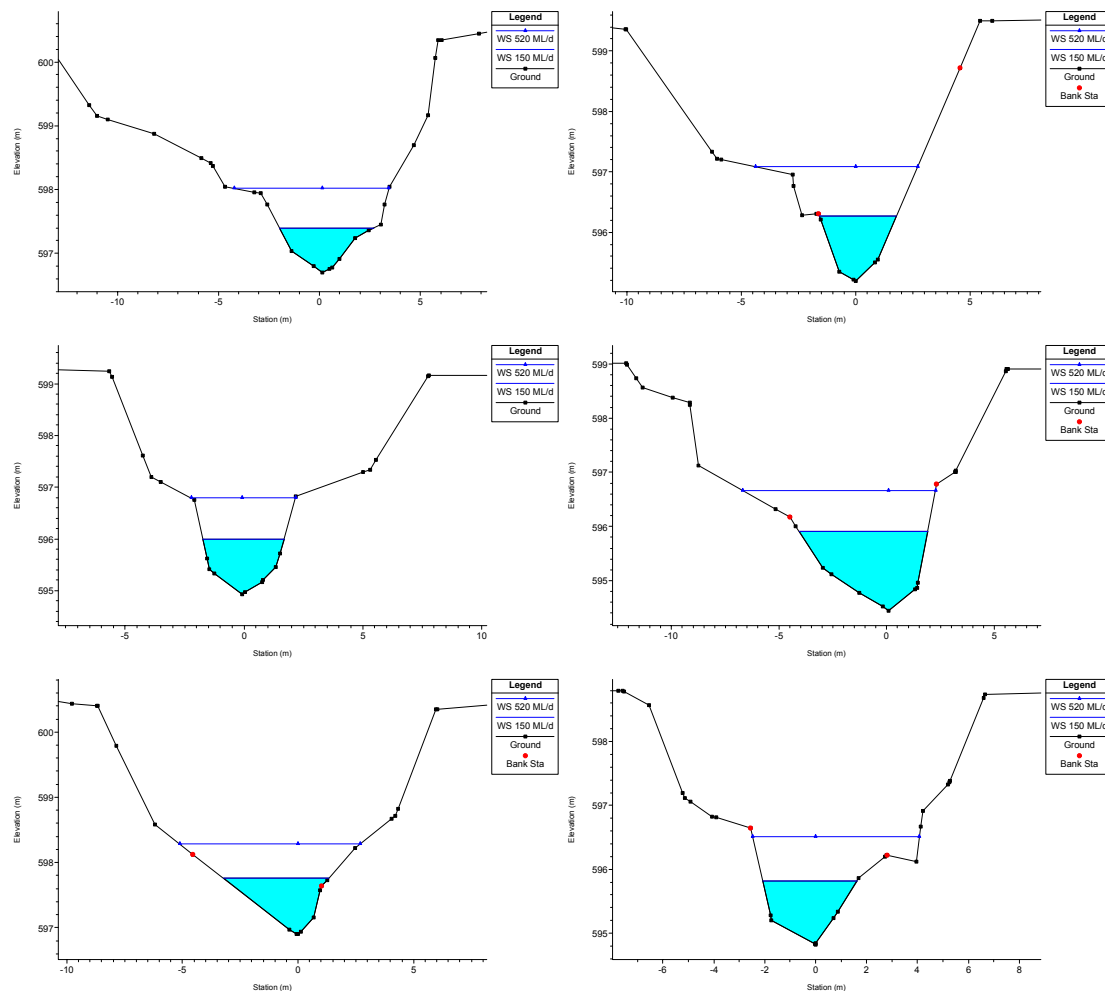


Figure 22. Selected transects at 150 and 520 ML/d. The top two are from Figure 21.

Similar to the Low Flow Freshes, High Flow Freshes are intended to occur as natural flows, related to rainfall events. The delivery of these freshes can only be through the management of diversions, so that after diversions, flows greater than 150 and 520 ML/d still occur in the system at the recommended frequency and duration (to be determined) during May to November. This may be done by, for example, restricting diversions during particular fresh events (until the flow exceeds the recommended level), or through limiting the overall diversion rates in the catchment, so that a sufficient proportion of natural flows pass to ensure that the recommendation is met.

Bankfull and Overbank flow

As for both Steels and Dixons Creek, no bankfull or overbank flows are recommended, due to the condition of the floodplain. But riparian vegetation would be of assistance to protect the banks from very high occasional flows that will occur.

Bankfull and Overbank flows:	No recommendations
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4.3.3 Summary Tables

Summary tables of the recommendations are presented in the FLOWS format (Table 16) and in a seasonal format (Table 17).

Table 16. Flow recommendations for Reach 7 – Pauls Creek– in the FLOWS format.

River	Pauls Creek		Reach	State Forest to Yarra River
Compliance Point	Upstream of Yarra River		Gauge No.	229245
Flow			Rationale	
Season	Magnitude	Frequency Duration	Objectives	Key Evaluation
All year	Cease-to-divert flow 15 ML/d		1a, 1b, 2a, 3a, 3b, 3c, 4, 5, 8a, 9	Area of fish habitat > 0.2 m deep, Fish passage (>0.12 m)
May-Nov	Fresh >150 ML/d		2b, 3c, 6a, 6b, 6c, 7a, 8b, 10	Low bench inundation
May-Nov	Fresh >520 ML/d		2b,3c, 6a, 6b, 6c, 6d(?), 7a, 7b, 8b, 10	High bench inundation

Table 17. Flow recommendations for Reach 7 – Pauls Creek– in a seasonal format.

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Cease-to-Divert Flow 15 ML/d											
				High Flow Fresh >150 ML/d							
				High Flow Fresh >520 ML/d							

4.3.4 Supporting Recommendations

Spring-fed pools that contain water for long periods of time, were identified in Pauls Creek (although not at the study site). These pools provide secure habitat for fish and other aquatic plants and animals, and should be seen as highly significant refuges. Catchment management activities (e.g. fencing and

protection from stock) is important for protecting these significant sites. The distribution of any such pools in Pauls Creek is currently unknown, but their distribution should be identified.

In-stream barriers present in the creeks (such as stock crossings, road crossings or small concrete off-take weirs) may prevent movement and migration of fish. These need to be identified and assessed.

The importance of the forested headwaters need to be recognised for their potential impacts on downstream reaches. Protection of these upstream reaches would assist in the delivery of good quality water and act as a potential seed source for riparian and in-stream vegetation.

While no recommendations have been made for bankfull or overbank flows, the rehabilitation of a riparian strip at the top of the channel would assist in protecting the channel from the rare very high flows that will occur in the future. Such high flows may cause significant damage to any unprotected sections at the top of the channel, causing erosion and sedimentation in the channel. Additional leaf material and large woody debris from this riparian zone would add value to in-stream processes (although the major floodplain functions will occur on benches in the channel itself).

5. Summary of Recommendations

To allow an easy comparison of the recommendations between reaches, a summary of all three reaches is presented below. This comparison shows a good consistency between the three reaches. The major difference is the lower Cease-to-Divert flow in Steels Creek over the Low Flow Season, due to the presence of deeper pools in the reach selected for study. However, the Cease-to-Divert flow over the High Flow Season is the same for all three reaches, emphasising the similarity in the baseflow channel form of the three reaches. The High Flow Freshes are of different magnitudes due to the different levels of benches in the reaches.

Reach 2 – Steels Creek from Jehosaphat Creek to Dixons Creek.

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Cease-to-Divert Flow 5 ML/d				Cease-to-Divert Flow 15 ML/d						C-t-D Flow 5 ML/d	
Low Flow Fresh >15 ML/d				High Flow Fresh >700 ML/d						15 ML/d	
				High Flow Fresh >2500 ML/d							

C-t-D – Cease-to-Divert

Reach 5 – Dixons Creek from the National Park to Steels Creek.

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Cease-to-Divert Flow 15 ML/d											
				High Flow Fresh >50 ML/d							
				High Flow Fresh >500 ML/d							
				High Flow Fresh >1250 ML/d							

Reach 7 – Pauls Creek.

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Cease-to-Divert Flow 15 ML/d											
				High Flow Fresh >150 ML/d							
				High Flow Fresh >520 ML/d							

6. Future directions

Clearly, the most significant information gap in the Steels, Pauls and Dixons Creeks is the lack of accurate and reliable flow data for the catchments. It seems unlikely that adequate data can be derived during the life of this FLOWS project. Therefore, the Streamflow Management Plan Committee needs to establish some process to generate adequate data during the life of the Streamflow Management Plan that can be used to extend the environmental flow recommendations developed in this report (including durations and frequencies of the recommended flows).

There appear to be few options to provide more reliable flow data in the short term (particularly the high flows):

- Revise the original Melbourne Water RORB modelling, extend it to cover the period 1998-2002 and examine the relationship with gauged flows.
- Utilise the Egis (2001) monthly flow data and generate a daily time series using a technique called “method of fragments” to disaggregate monthly flows.
- Re-calculate the SKM (2003) data with different model assumptions to potentially generate more representative high flows.
- Develop a new streamflow series based on a transposition of streamflows in a nearby catchment such as Diamond Creek.
- Develop a new streamflow series based on a rainfall-runoff model without reference to the gauged data.
- Wait until longer-term flow data are available from the gauges on Steels and Pauls Creek and re-calculate flows based on more comprehensive data.

It seems unlikely that any modelling will adequately reflect the recent gauged flow data, given the extremely dry conditions over the time since the gauges was established. However, the intent of flow modelling for environmental flow purposes is not to accurately depict flows on a particular day in the past, but to present a realistic picture of the likely flows in the future (in terms of seasonal and annual patterns, return intervals of particular flow events etc.). While extreme events (such as the recent low flow years) may not be precisely reflected in the flows, the majority of the modelled flow record should reflect flow characteristics in other, more “normal” years, and could be suitable for environmental flow recommendation purposes.

It is therefore suggested that the poor fit between the modelled flow and recent gauged results be seen as an artefact of the extreme conditions. Modelled flows in other years are more likely to represent realistic predictions for future flow characteristics. Therefore, recalculation of the SKM data, development of a transposed streamflow from a nearby catchment, or development of a new streamflow series would seem to be the most appropriate short-term solution.

Once this is done, the recommendations can be refined to include frequency and durations of the recommended flows.

7. References

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