APPENDIX F: Environmental Flows Assessment for the lower St Pauls River

1. Description of study reach

The reach of the St Pauls River that was used for environmental flows assessment is located about 4 km upstream of the junction with the South Esk River at the township of Avoca. At this location, the river has an active channel width of about 2-5 m which, during low flows, is comprised of a series of shallow pools (water depth <0.75 m) connected by relatively short and shallow riffles. Unlike sections of the river upstream of this site where, during extremely dry periods, no surface water is evident and water appears to travel downstream through macropores beneath the bed of the river, at these times, discernible surface flow remains in this reach.

At the study reach, the substrate of the river is composed almost entirely of dolerite rock of pebble and gravel size categories, with some boulder and bedrock present in sections where there are rapid changes in gradient. Based on surveys of thalweg*[*] elevation, the overall gradient of the river at this point was estimated to be about 0.0018 (or 1.8 m fall per kilometre of river distance).

The shallow pools within the river at this site are fringed by emergent macrophytes and the bed of the river, in both the pools and riffles, is generally covered by a thick layer of benthic algae and a fine layer of silt. Although some parts of the active river channel are steep and indicate active erosion processes, most banks are covered by either small stands of woolly teatree (*Leptospermum lanigerum*) or a mixture of introduced and native grasses and herbaceous plants (Plates F1 & F2).

Plates F1 & F2: Photos of the lower St Pauls River showing grasslands covering the minor flood bench, remnant stands of woolley teatree that line the river channel, and macrophyte beds and herbaceous plants that fringe shallow pools.

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[*] for a definition of these words or terms, see the Glossary in the main report.

2. Environmental Values and Objectives

In the CFEV database, the middle and lower reaches of the St Pauls River have been assessed as having a 'low' to 'medium' degrees of naturalness (CFEV 2005); however, this stretch of river has a 'very high' conservation management priority[*]. According to the CFEV database, the main values that drive the conservation management priority for this part of the river relate to its geomorphology and the terrestrial and riparian vegetation community through which it flows. There are also a number of special values that relate specifically to the aquatic ecosystem, namely:

- Endemic freshwater snails (*Hydrobiid* complex*)*
- South Esk freshwater mussel *(Velesunio moretonicus*)
- High priority riparian flora communities
- Floodplain *Poa* grassland

Additional to these special values, other important biophysical classes are also highlighted in the CFEV database. These relate to: the fish assemblage that inhabits the area, freshwater crayfish that occur within the region, and the characteristic aquatic plant communities that occur in the 'broadwaters' of the South Esk River and Macquarie river systems. All of the information that was obtained from the CFEV database and used to develop environmental objectives for the reach, is presented and discussed within the broader context of the South Esk catchment in Chapter 2 of the main environmental flows report.

In summary, an environmental flow for the middle and lower reaches of the St Pauls River should aim to provide sufficient water to meet the needs of:

- the fish community occurring in the river (particularly native fish),
- aquatic and riparian plant communities within the river corridor,
- endemic freshwater snails and mussels,
- riverine productivity and basic foodweb structure, and
- ongoing geomorphic processes.

Based on this information, Table F1 presents the environmental objectives that an environmental flow allocation should address and the flow components that are required to achieve these objectives. Further information about these flow components, such as their frequency, timing and magnitude, are provided in Chapter 2 of the main report; that report also provides references to the published literature that illustrate the importance of these flow components in riverine ecosystems.

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[*] for a definition of these words or terms, see the Glossary in the main report.

Table F1: Environmental objectives of the environmental flow assessment for the lower South Esk River, and important components of the flow regime that support the objectives.

Environmental objectives for the river reach under consideration	**Flow components that are important* in maintaining the environmental objectives, and their scientific basis**
Maintain healthy populations of native fish (particular southern pygmy perch)	• Seasonal occurrence and magnitude of freshes and minor flood events that act as triggers for migration and dispersal • Dry season water levels in remnant pools to maintain adequate instream habitat • High flow events that flush-out fine sediments and rejuvenate and maintain spawning habitats
Maintain existing macroinvertebrate community diversity and abundance	• Seasonal pattern of change in baseflow and flow variability; frequency and occurrence of freshes and high flow events to maintain cues for dispersal. • Bankfull and overbank flows to maintain riparian vegetation as sites for breeding and oviposition, and source of instream wood and organic material for food and habitat • Minimum flows to support adequate instream habitat
Provide habitat of good quality for instream biota (macroinvertebrates and freshwater mussels)	• Summer and autumn freshes to control unpalatable and habitat-smothering filamentous algae • Flood events that import and move large woody debris, maintain bank undercuts, redistribute fine organic matter and flush-out fine sediments from riffle macropores • Minimise the duration of extreme low-flow events that may impact on the habitat of endemic freshwater mussels
Maintain healthy instream macrophyte communities and current spatial coverage & distribution	• Maintain wetting/drying regime in shallow, fringing lateral benches and small riparian wetland patches • Maintain seasonal flushes that prevent excessive and prolonged smothering by epiphytic algae
Maintain productivity and benthic metabolism of riverine ecosystem	• Water level in pools and runs that maintain hydraulic head above riffle zones and sustain flow through interstitial pores • Seasonal flow events that flush-out attached algae, mobilise bed material and re-set colonisation by biofilms
Maintain populations of platypus	• Summer low-flows and winter high flows for foraging and maintenance of habitat for food organisms • Flows that maintain riparian habitat that is suitable for burrows
Sustain existing riparian and floodplain vegetation	• Bankfull flows and larger flood events to recharge local groundwater system and provide access to groundwater during dry periods • Freshes and floods to aid recruitment by dispersing seeds, and stimulating regeneration through disturbance
Maintain current geomorphic character and processes	• Flood events that mobilise varying size-fractions of bed material, create 'new' patches of instream habitat and physical features, and maintain scouring and transport processes • Overbank flow events that maintain larger-scale physical features and processes in floodplains

*For a more detailed list and explanatory text, see Chapter 2 of the main report.

Table F1 clearly shows that environmental flow provisions should not simply focus on providing a ‘minimum flow’ during the dry months, but rather, they need to provide adequate provisions of water across the entire flow regime. However, prior to undertaking the environmental flow assessment, the impact of current water use on the flow regime of the study site should be examined. This topic is briefly covered in the next section.

3. Impact of current water use on flows

A risk assessment has been carried out in the main report by examining the degree to which the hydrological regime in the South Esk catchment has been altered from its natural state as a result of water use (Chapter 4); a conceptual understanding of the river system was also used in these analyses. The hydrological analysis of the lower St Pauls River sub-region (summarised in Chapter 3 of the main report) shows that the current flow regime is essentially unmodified, and that, presently, water use in the upper catchment impacts only marginally on the low flow component of the flow regime. Subsequently, the following environmental flow assessment for the lower St Pauls River focuses on providing information on what may constitute an environmentally appropriate minimum flow, as well as flood flow provisions that are likely to maintain the identified environmental values. Given that, currently, the level of water abstraction in this sub-region poses minimal risk to existing environmental values, the recommendations made in the following sections are aimed at preserving these values even if water use increases in this region in the future.

4. Minimum flow analysis

During this study, no hydraulic or biological information was collected from the lower St Pauls River. Instead, the most of the biological and all of the elevation data that were used for this assessment were taken from earlier unpublished work conducted in this reach during 2000; these data were collected under the minimum flow assessments program of DPIWE. Additionally, biological information was sourced from the CFEV database and other researchers that have previously worked in this area. Details of these sources are included in Chapter 4 of the main report, where the methodology for this assessment is discussed in more detail.

The minimum flow requirements for the lower St Pauls River at this site were assessed by using habitat preference information (i.e. preferred depths and velocities) for relevant fish species, freshwater mussel *V. moretonicus*, freshwater crayfish and platypus freshwater crayfish (*Astacopsis franklinii*) and platypus (*Ornithorynchus anatinus*). To incorporate the needs of aquatic macroinvertebrates, relationships between the abundance of macroinvertebrate communities and river discharge from other studies in the South Esk River system and elsewhere in Tasmania were also used. Some of the macroinvertebrate habitat preference data were derived from samples that were collected by DPIWE in 2000 in the study region. These data include information relating to taxa from the families Hydrobiidae, Ceinidae, Baetidae, Chironomidae, Leptophlebiidae, Conoesucidae and Paramelitidae.

Because each of these components of the faunal community have different habitat and flow preferences and, therefore, different habitat-use curves, an attempt was made to combine the curves for each to provide an estimate of habitat availability with changes in flow for the assemblage as a whole. However, this was not possible because of significant differences between the habitat requirements of macroinvertebrates and the mobile taxa (i.e. fishes, crayfish and platypus).

The mobile taxa that live predominantly above the bed of the river tend to prefer water depths and velocities that occur under lower flows. The habitat-use curves for these taxa were combined to form a mobile fauna assemblage curve (Figure F1). This habitat-use curve includes the habitat preferences for adult and juvenile brown trout (*Salmo trutta*). Although brown trout are an introduced species, they are highly valued for recreational angling in this catchment. Furthermore, their inclusion did not greatly alter the rating curve that was derived only for native species. The habitat-use curve that was generated for this assemblage most closely resembles the curves for southern pygmy perch (*Nannoperca australis*) and juvenile blackfish (*Gadopsis marmoratus*) at this reach, which, of all the fish species present, have the highest priority in terms of conservation.

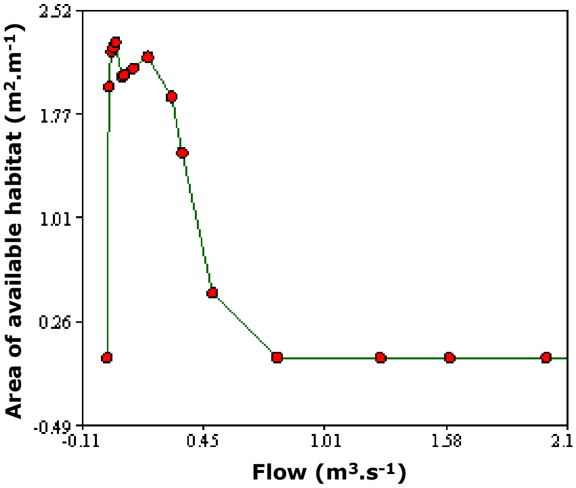

Figure F1: The 'mobile' fauna assemblage habitat-use curve for the lower St Pauls River. This rating curve, which shows how habitat availability varies with changes in flow, is derived from the amalgamated information on habitat preferences for native and introduced fish, crayfish and platypus.

In contrast, the habitat-use curves for freshwater mussels and macroinvertebrate abundance, which have been combined to produce a 'benthic' fauna habitat-use curve (Figure F2), suggests that the habitat for this component of the riverine community is much more prevalent in the lower St Pauls River. This is indicated by the higher peak value on the y-axis. Preferred habitat for this assemblage is also available over a much greater range of flows (0.5-18 $m^3.s^{-1}$) in the study. This assemblage is much less mobile and reliant on the habitat provided by the substrate within the river channel, and is clearly unaffected by the greater water depths and higher velocities that occur at higher flows.

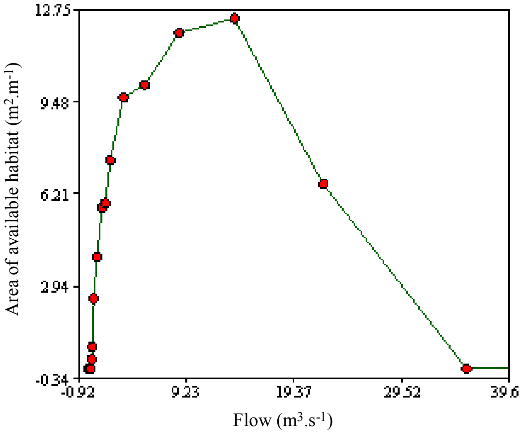

Figure F2: The 'benthic' fauna assemblage habitat-use curve for the lower St Pauls River. This rating curve, which shows how habitat availability varies with changes in flow, is derived from the amalgamated information on habitat preferences for the South Esk freshwater mussel (*V. moretonicus*) and general macroinvertebrate abundance.

The habitat-use curve for 'mobile' fauna (Figure F1) shows that the maximum amount of habitat available for this assemblage under any flow is about 2.25 m^2 per metre of river length and this occurs when flow is approximately 0.2 $m^3.s^{-1}$ (17 $ML.day^{-1}$). These findings are supported by the known habitat preferences of pygmy perch: they use habitat provided by the macrophyte beds along the fringes of the stream, where there is instream cover and low water velocities. At flows of this magnitude, fringing macrophyte beds are likely to have a sufficient depth of water for use by these small-sized fish and suitable local water velocities to provide optimal conditions for habitation. Higher flows are likely to 'wash-out' these habitats and force the fish to seek refuge in other non-preferred habitats.

Having developed these combined habitat-use curves that show how habitat availability for 'mobile' and 'benthic' fauna assemblages changes with flow, the 40-year time series of 'natural' streamflow from the hydrological model for the catchment could then be converted to a time series of habitat availability. However, because the focus of this component of the study is on the provision of minimum flows, and the fact that both curves can not reasonably be applied to data from high-flow periods, the 'natural' streamflow record was filtered to separate out the baseflow component. The RAP Time Series Analysis module contains a baseflow separation filter (the Lyn-Hollick digital filter) which allows a time series of baseflow to be generated. Using an alpha-value of 0.95 for this filtering process, a 40-year baseflow time series was created and this was than transformed to habitat availability for 'mobile' and 'benthic' fauna assemblages using the relevant rating curves.

Portions of these four time series are presented in Figure F3. This figure illustrates the proportion of streamflow (red line) that occurs as baseflow (blue line), and how habitat availability for each of the fauna assemblages (orange and green lines) varies with changes in flow conditions. This plot shows that at higher baseflows, the availability of habitat for 'benthic' fauna is greater, whilst for the 'mobile' fauna assemblage, the reverse occurs. Although this implies that habitat availability for the 'mobile' fauna assemblage is near to zero at times of higher flow, during these periods, the species within this assemblage will seek refuge in low-velocity areas such as within snag piles, behind large boulders and, for crayfish, in banks or bed of the river. Thus, whilst the amount of preferred habitat is reduced, refuge habitats will always be available as long as the physical structure of the river remains in a natural condition.

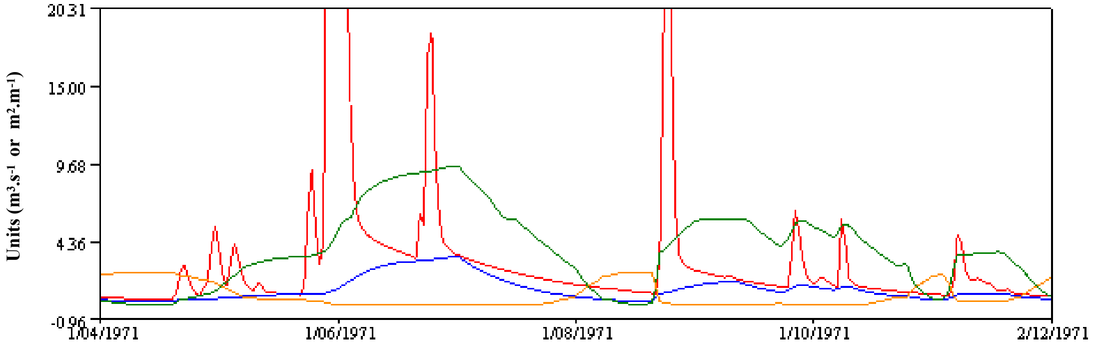

Figure F3: Time series of modelled 'natural' flow (red) and baseflow (blue) for the lower St Pauls River, along with modelled changes in habitat availability for the 'mobile' fauna assemblage (green) and 'benthic' fauna (orange) between April and December 1971.

The data that produces this graph can be summarised and plotted in the form of a chart showing the average amount of habitat available under 'natural flows' on a monthly time-step (Figure F4). It shows that the two faunal assemblages react differently to changes in flow conditions, with the relative proportion of habitat for 'mobile' fauna declining in winter, whilst, for the 'benthic', fauna the reverse is true. As mentioned above, this is partly an artefact of the modelling used for the assessment. It is worth noting also, that the data used to derive the curves was collected during the summer months and reflects habitat preferred by these fauna during the low-flows of summer.

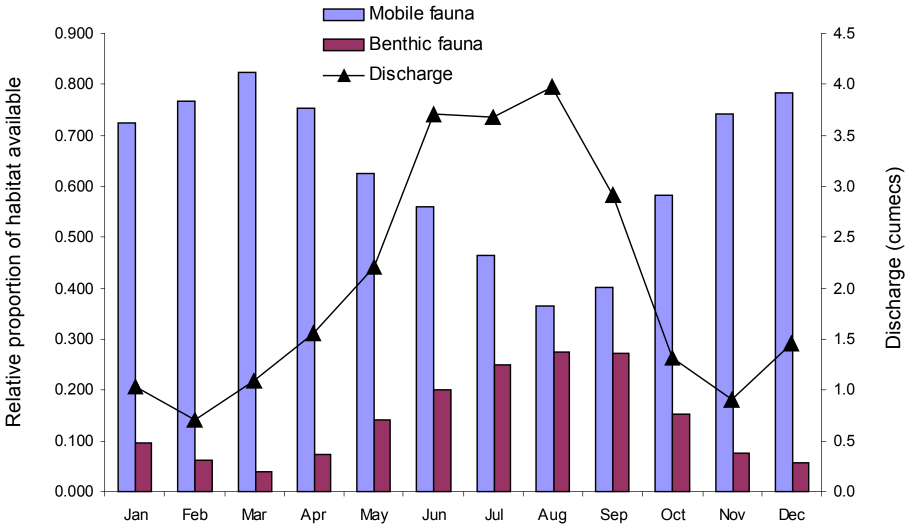

Figure F4: Average proportion of stream area available as preferred habitat for 'mobile' fauna (blue bars) and 'benthic' fauna (purple bars), and changes in monthly average 'natural' flow (black line) in the lower St Pauls River. The proportion of habitat available is a function of the area that is actually available under average monthly baseflows relative to the maximum area this is available at the preferred flows of each assemblage.

Clearly, during the drier months of November to April, when average daily baseflow falls below 0.5 $m^3.s^{-1}$(43 $ML.day^{-1}$), habitat for 'benthic' fauna limited (Figure F4). Unlike taxa in the 'mobile' fauna assemblage, during periods of low flow, the 'benthic' fauna are less able to move out of areas that are drying-out and take refuge in the remnant pools. Therefore, during November to April, minimum flow recommendations are primarily aimed at providing adequate habitat for the taxa in the 'benthic' fauna assemblage.

To assist in determining a minimum flow level, the time series of habitat area available for macroinvertebrates as derived from the conversion of the 43-year modelled record for 'natural' baseflows, was statistically analysed. The daily data for each month was aggregated and from these subsets of data, percentiles of habitat availability were calculated. The results of these analyses are graphically presented in Figure F5, which shows the monthly change in selected percentiles of habitat area available for the macroinvertebrate assemblage at the lower St Pauls River. There is a significant decline in the amount of habitat available for benthic fauna during February and March. During these months, the 50th percentile is at or near to zero. This is because the 50th percentile of these data lies to the lower extent of the rating (Figure F2), which is near vertical (very small changes in flow cause large drops in habitat area); this is not inappropriate, seeing as the river during summer verges on drying-up.

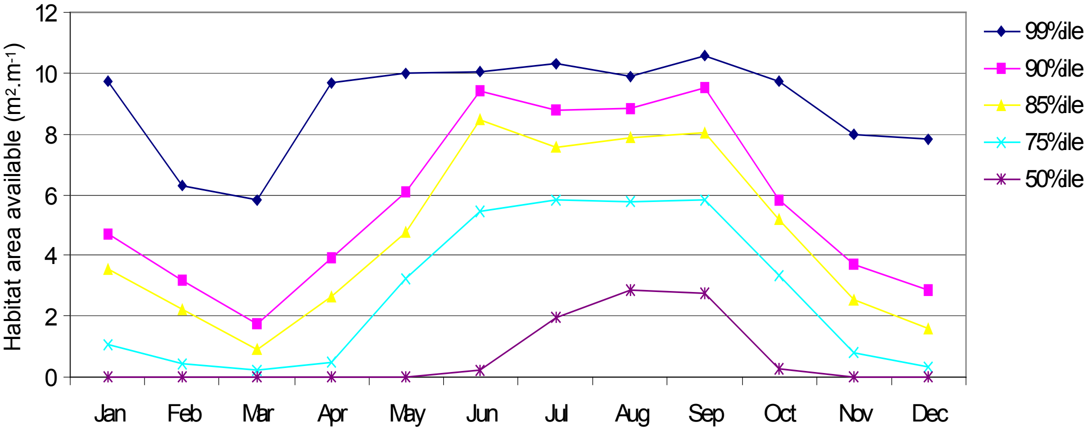

Figure F5: Monthly change in selected percentiles of habitat area available for the 'benthic' fauna assemblage in the study reach on the lower St Pauls River using modelled 'natural' flows from 1960 to 2003.

Whilst a similar analysis of the habitat data for 'mobile' fauna was undertaken, it is not presented. However, that analysis showed that throughout the drier months (November to April), amounts of habitat that are ≥40th percentile are maintained at or above 2 $m^2.m^{-1}$, which shows that habitat is available for the 'mobile' fauna assemblage during low flow conditions.

Table F2 provides an indication of the flows (as a daily averages) which provide vary amounts of habitat for the 'benthic' assemblage within this study reach. Knowing what flows will provide what percentage of instream habitat for benthic fauna provides a good basis for making recommendations for minimum environmental water provisions. However, in developing minimum flow recommendations, some consideration must also be made for flows that maintain longitudinal connectivity and the wetting of lateral benches within the river channel where fringing macrophytes occur. This latter habitat is a significant feature of the lower river system, provides the main habitat for native fish and is one of the main features supporting macroinvertebrate diversity in the river.

Table F2: Monthly 85th, 75th and 50th percentiles of instream habitat for benthic fauna in the lower St Pauls River derived from 'natural' baseflow data, and the corresponding flow which provides these amounts of habitat.

Month	85%ile habitat ($m^2.m^{-1}$)	Flow that maintains 85% of habitat ($m^3.s^{-1}$)	75%ile habitat ($m^2.m^{-1}$)	Flow that maintains 75% of habitat ($m^3.s^{-1}$)	50%ile habitat ($m^2.m^{-1}$)	Flow that maintains 50% of habitat ($m^3.s^{-1}$)
Jan	3.53	0.70	1.05	0.37	<0.01	0.18
Feb	2.22	0.46	0.40	0.29	<0.01	0.18
Mar	0.88	0.36	0.24	0.26	<0.01	0.18
Apr	2.63	0.52	0.49	0.31	<0.01	0.18
May	4.78	1.02	3.23	0.65	0.02	0.20
Jun	8.45	2.61	5.45	1.23	0.22	0.24
Jul	7.57	2.15	5.84	1.42	1.98	0.45
Aug	7.85	2.30	5.76	1.41	2.86	0.56
Sep	8.01	2.43	5.84	1.42	2.75	0.54
Oct	5.11	1.14	3.33	0.66	0.24	0.26
Nov	2.56	0.51	0.81	0.36	<0.01	0.18
Dec	1.58	0.42	0.31	0.27	<0.01	0.18

Inspection of the elevation data in the hydraulic model for the reach, along with field observations made by DPIW staff, suggests that during very dry conditions, the lower St Pauls naturally forms a series of pools that are remain marginally disconnected. Because of this, and the very low gradient of this part of the river system, a flow of only approximately 0.05 $m^3.s^{-1}$ (4 $ML.day^{-1}$) will maintain connectivity between pools. In some sections, surface flow may cease, but water appears to flow beneath the bed of the river due to the composition and porosity of the river-bed.

Complete inundation of all lateral instream benches, where the fringing aquatic plants are situated, occurs at a discharge of approximately 2.7 $m^3.s^{-1}$ (233 $ML.day^{-1}$). In recommending flows that will inundate this area, it is recognised that these areas are a product of variable wetting and drying, and do not require permanent water. Indeed, a variable water level regime promotes diversity in these plant communities (Brock, 2000) and is a requisite for their long-term health and viability.

4.1 Recommendations for minimum flow provisions

Although the data in Table F2 provide useful information regarding the amount of habitat that is available under different low flow conditions, using this information to make recommendations regarding minimum flow allocations requires some discussion of ecological consequences.

The ‘habitat availability’ values in Table F2 were calculated using baseflow data that were extracted from the ‘natural’ flow data provided by the hydrological model for the catchment. These baseflow data do not contain flow variability that is associated with surface runoff and they represent minimum flows that would occur in the absence of agricultural water extraction.

Given the method used to generate the habitat availability data, it is clear that adopting a minimum flow that aims to maintain 85% of instream habitat (the 85% habitat maintenance flow) is the most conservative option. At the other end of the spectrum, adopting a minimum flow level that will maintain only 50% of instream habitat is less likely to sustain a healthy and productive aquatic ecosystem. At flows of this magnitude (<0.2 $m^3.s^{-1}$ or 17 $ML.day^{-1}$ over most of the irrigation season), the wetted surface area of the river is very low, as the river verges on becoming ephemeral, and habitat for both benthic invertebrates and fish are naturally restricted to remnant pools.

The rationale for adopting a ‘median condition’ has been used in other environmental flow studies where researchers have sought to establish a ‘standard’ or ‘reference’ condition. Adopting a median value recognises environmental variation, and the balance between extreme stress and abundant provision. Adopting a median value recognises environmental variation, and the balance between extreme stress and abundant provision. Whilst adopting a median is less conservative than adopting an 85th percentile, if it is considered as an ‘absolute limit’ (i.e. as a cease-to-take flow), it will restrict the temporal extent of flow-related ‘stress’ to the aquatic ecosystem. Adopting the 50% habitat maintenance flow as a ‘cease-to-take’ limit means that the ecosystem will continue to be exposed to periodic ‘acute stress’ during periods of extreme low-flows, but it will limit the risk of ‘chronic stress’ associated with prolonged and frequent exposure to these conditions.

On this basis, it is recommended that a minimum environmental flow for the lower St Pauls River should maintain 75% of instream habitat for aquatic invertebrates, and this is provided on a monthly basis to ensure that seasonal changes in baseflow are preserved. This level of flow should be adopted as the ‘sustainable limit’ for water allocation, as any allocation of water beyond this is likely to lead to an increased risk of ‘chronic’ flow-related stress to the aquatic ecosystem. For daily management of water use, the 50% habitat maintenance flow is recommended as providing an appropriate ‘cease-to-take’ flow. The monthly flows that correspond to these levels are provided in Table F3.

Table F3: Recommended environmental flows and 'cease-to-take' flows for the lower St Pauls River.

Month	Environmental flow (75% habitat maintenance flow) ($m^3.s^{-1}$)	Cease-to-take flow (50% habitat maintenance flow) ($m^3.s^{-1}$)
Jan	0.37	0.18
Feb	0.29	0.18
Mar	0.26	0.18
Apr	0.31	0.18
May	0.65	0.20
Jun	1.23	0.24
Jul	1.42	0.45
Aug	1.41	0.56
Sep	1.42	0.54
Oct	0.66	0.26
Nov	0.36	0.18
Dec	0.27	0.18

5. Flood flow analysis

In contrast to low flows, 'flood flows' or 'high flows' comprise the majority of the variability in the flow regime of a river. Flow events from this part of the hydrograph range from 'freshes' created by brief rainfall events, 'channel maintenance' events that occur 5-10 times per year, and 'floodplain inundation' events that are commonly perceive as major floods in the landscape. Each of these flow events are important in maintaining the form and character of the river (Gippel, 2001), as well as creating a diversity of hydraulic environments that support instream flora and fauna (Biggs *et. al*., 2005; Thoms, 2006). It is important, therefore, when making judgements about components of the flow regime that are required to sustain river ecosystems, some consideration is made of the characteristics (e.g. timing, frequency, magnitude, rate of rise and fall, etc.) of these events. To do this, a method called 'high spells' analysis has been used (Marsh *et al.,* 2003).

5.1 High Spells Analysis

High spells analyses, using the RAP software package, were used to examine the nature and timing of flow pulses, which tend to occur several times per year and are not normally considered to be major flow events. This technique involves setting flow thresholds (that are of ecological and/or geomorphological importance) and analysing flow time series' to determine statistics such as their frequency, timing, and duration.

Two high spells analyses were conducted for the lower St Pauls River (Table F4). One threshold represented the level at which minor benches within the main channel are flooded; this level also coincides with the upper extent of fringing macrophyte beds. As mentioned in the previously, the hydraulic model of this study reach suggests that the flow at which fringing macrophyte beds are flooded throughout most of the study reach is about 2.7 $m^3.s^{-1}$ (233 $ML.day^{-1}$). Scouring of attached algae that has built up during extended dry periods is also likely to occur at flows of this magnitude or greater.

The second high spell analysis used the 7 $m^3.s^{-1}$ flow threshold (Table F4), as this was determined to be the level at which the active section of the main channel was entirely flooded by water (i.e. bank-full discharge). Within this study reach, this high spell threshold was found to coincide with the 5% exceedence flow. Bank-full discharge is often viewed as a key variable in the maintenance of geomorphic processes and the physical features of river channels (Gordon, *et. al,* 2004); it is also important for the transport of sediment and nutrients (Newbury and Gaboury, 1993).

The high spells analyses show that flow events that are not considered 'floods' occur most frequently in the lower St Pauls River during winter. Events that inundate fringing reed beds occur on average about 4 times per year. On average these events last for about 15 days, but there is considerable seasonal variation, with events in summer lasting only about 8 days, whilst in winter and spring, events exceeding this threshold tend to last for > 17 days. Channel maintenance flows (5% exceedance events) are more likely to occur in winter. On an annual basis, flow events exceeding this threshold occur about 5 times every 2 years and last for between 5 and 7 days.

Table F4: Summary of 'high spells' analyses of the 'natural' flow data for the lower St Pauls River. The 2.7 $m^3.s^{-1}$ threshold corresponds to the flow at which minor benches within the active channel are inundated and the 7 $m^3.s^{-1}$ threshold corresponds to 'bank-full' flows.

	2.7 $m^3.s^{-1}$ flow threshold (or 233 $ML.day^{-1}$)			**5% exceedence (7 $m^3.s^{-1}$ or 605 $ML.day^{-1}$)**		
	Average frequency	Average duration (days)	Average magnitude ($m^3.s^{-1}$)	Average frequency	Average duration (days)	Average magnitude ($m^3.s^{-1}$)
Spring	1.4	11.9	14.3	0.5	4.9	31.6
Summer	0.8	6.8	19.5	0.3	5.1	48.4
Autumn	1.1	9.3	32.4	0.6	6.3	52.5
Winter	2.2	14.3	33.3	1.8	4.6	41.3
Annual	5.2	10.7	22.8	3.2	5.2	40.7

The data in Table F5 show the average duration and rates of rise and fall in the hydrograph for the river at the St Pauls study reach. It provides additional information on rates of change in flow that occur, and illustrates that the river responds rapidly to runoff, with shorter durations (and larger rates) of rise in flows in comparison to falls. Whilst these figures are informative, they are most valuable when viewed in conjunction with figures derived for other locations in the river system. In comparison to the rates of rise and fall in upper South Esk River at 'Malahide' (9 $m^3.s^{-1}.d^{-1}$ and 6.9 $m^3.s^{-1}.d^{-1}$ respectively), in the lower St Pauls River, high flow events rise less rapidly and their average duration is twice as long. This is likely to be due to the greater infiltration that occurs in the St Pauls catchment, the lower gradient of the river and the smaller size of the channel which limits its capacity to transport water. These data also suggest that groundwater makes a greater contribution to recession flows in the St Pauls River.

Table F5: Average duration of rise and fall in flow and rates of change in flow in the lower St Pauls River.

Statistic	Lower St Pauls River
Mean duration of Rises (days)	2.4
Mean rate of Rise ($m^3.s^{-1}.d^{-1}$)	2.6
Mean duration of Falls (days)	14.9
Mean rate of Fall ($m^3.s^{-1}.d^{-1}$)	1.21

Tables D4 & D5 show the average seasonal distribution, size, duration and rates of change of ecosystem-relevant flow pulses, but flows may also vary between years. Figure F6 illustrates inter-annual variations in hydrographs for the years 1996 and 2000, along with the two 'high spell' flow thresholds. Figure F6 highlights the substantial variation that may occur between years in the timing of high flow events. In 1996 (which was the drier year), only one event reached the 'channel maintenance' threshold of 7 $m^3.s^{-1}$ (605 $ML.day^{-1}$) and this occurred in the middle of winter. During 2000, when the overall yield from the catchment was markedly higher, there were large events in both summer and winter, with a number of smaller events occurring throughout winter and spring, many of which nearly reached or exceeded the 2.7 $m^3.s^{-1}$ (233 $ML.day^{-1}$) 'bench inundation' threshold.

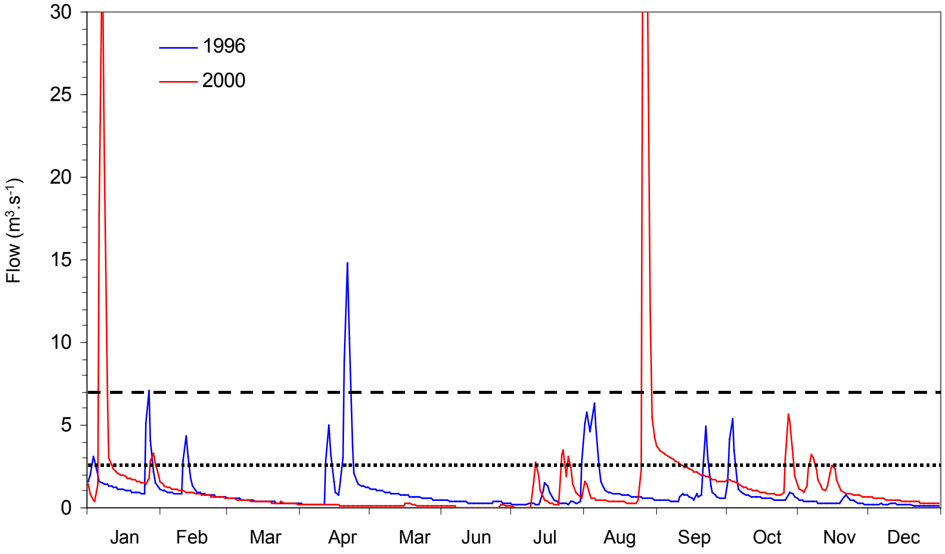

Figure F6: Average daily 'natural' flow in lower St Pauls River upstream during 1996 and 2000. Horizontal dotted lines denote 'lateral bench inundation' (lower) and 'channel maintenance' (upper) flow thresholds.

Given that the current availability of water for agricultural use during the summer is limited and water managers are encouraging the extraction of water during winter – spring, these high spells analyses provide a good basis from which to make recommendations regarding environmentally sustainable extractions of flood water. One of the environmental objectives under the Tasmanian Environmental Flows Framework is to maintain, as far as practicable, the natural pattern of flows. The main environmental and ecological reasons for this are that flooding: provides numerous environmental benefits in terms of nutrient and sediment dispersal, acts to maintain the river form and character, distributes wood and organic material upon which instream fauna rely, and rejuvenates riparian vegetation communities. Bearing these various roles in mind, the following recommendation is made.

5.2 Recommendations for allocation of flood water

It is recommended that the extraction of flood water be restricted to periods when flows exceed 2.7 $m^3.s^{-1}$ (233 $ML.day^{-1}$). Extraction of flood water should not be allowed to significantly affect the duration of smaller events that do not exceed 7 $m^3.s^{-1}$. To ensure this, we recommend that only 50 $ML.day^{-1}$ be made available for extraction for up to 7 days once the threshold is exceeded or until flow drops back below the threshold. This volume of water represents about one fifth of the flow threshold, and is considered to be relatively conservative in terms of protecting the shape of high-flow events and the natural pattern of the flow regime. Considering that events exceeding 2.7 $m^3.s^{-1}$ occur on average about 5 times per year, this makes about 1,750 ML or water potentially available on an annual basis. No seasonal boundaries to this rule are proposed.

Under the recommended flood harvesting rules outlined above, all flow events occurring below the 2.7 $m^3.s^{-1}$ flow threshold are protected. The ecological value of these smaller events is particularly important during prolonged periods of low-flow, as they provide some variability when conditions have been static, and have been viewed as having a role in 'relieving stress' on river systems (Poff, *et al.*, 1997; Webster, *et al*., 2000). In a dry year, these events may constitute a large proportion of the variability in the flow regime, and it is these events that are most impacted by the proliferation of dams within catchments. In the case of the South Esk catchment, these events are presently provided some measure of protection by the flood harvesting rules (discussed above) that were instituted by Hydro Tasmania following their South Esk Water Management Review in 2003. Under this rule, the combined flow at monitoring sites on the Meander Macquarie and South Esk rivers must exceed 70 $m^3.s^{-1}$ before flood water can be extracted from any of the three river systems.

It should also be recognised that recommendation made here needs to be considered in light of similar recommendations made for locations further down the South Esk River system. Any water that is allocated from the catchment above this point needs to be accounted for in downstream management and as part of an overall 'extraction cap' for the catchment.

6. Summary

The environmental values that have been identified for the lower reaches of the St Pauls River relate to the high priority riparian and floodplain plant communities, highly valued aquatic fauna and fish, and the processes that maintain instream habitat and productivity. In providing environmental flows to maintain these values, the objective has primarily been to retain natural variability in the flow regime as much as possible. To do this, recommendations have been made regarding monthly minimum flow provisions and extraction rules aimed at preserving the magnitude and duration of moderate and high flow events.

Monthly minimum flows have been recommended with the aim of maintaining sufficient habitat to sustain benthic fauna and the fish community during dry periods. These may be incorporated into the Water Management Plan for the catchment in the form of allocation limits and 'cease-to-take' triggers at the current stream-gauging station. Although the primary aim has been to assist with the management of agricultural water extraction during the irrigation period (October to April), data has been provided that covers the rest of the year, and should guide the allocation of water during winter too.

Basic rules have been recommended regarding the extraction of water during times of flood, and these need to be considered in conjunction with rules for water extraction that presently exist as part of Hydro Tasmania's water management process, and similar recommendation that have been made elsewhere in the catchment.

It is anticipated that these recommendations will preserve the natural character of the flow regime sufficiently to maintain the freshwater values that have been identified for the lower St Pauls River into the future.