APPENDIX E: Environmental Flows Assessment for the Nile River at 'Glen Mavis'

1. Description of study reach

This site on the Nile River is located approximately 2.5 km upstream of the township of Nile (TASMAP 5238, E529537 N5389904). At this location, the river has an active channel width of about 12-26 m. During low flows, this reach contains defined pools (depths typically >0.8 m) that are connected by glides and shallow riffles (depths typically <0.5 m).

The river at the study reach is a freestone stream* with substrates of cobble, pebble and gravel size categories being dominant in the main channel. The spatial arrangement of these substrates in the main channel and scoured areas of riverbank, indicate the frequent occurrence of high flows and over-bank floods (i.e. this reach has a very active river channel). Based on surveys of thalweg* elevation, the overall gradient of the river at this site was estimated to be approximately 0.0014 (or 1.4 m of fall per kilometre of river distance).

This site is located in an area of the South Esk catchment that is used for agriculture (grazing and cropping) and has been substantially modified from its natural condition. Whilst some parts of the river channel are steep and indicate active erosion processes, the riparian zone of this reach is quite well vegetated. Most of the northern bank and it immediate floodplain is covered by a mixture of native vegetation including woolly teatree (*Leptospermum lanigerum*), *Eucalyptus* spp., dogwood (*Pomaderris* sp.) *Poa* grasses and herbaceous species (Plates E1 & E2). The southern river bank and its immediate floodplain, which is on the fringe of open paddocks of pasture and crops, is less vegetated and contains a mixture of native species (mostly mature *Eucalyptus* spp. and woolley teatree) and exotic species such as European gorse (*Ulex europaeus*), hawthorn (*Crataegus monogyna*) and pasture grasses. During low flows, the river bed in both pools and glides is generally covered by a very thick layer of benthic algae and a fine layer of silt. This reach also contains instream habitats such as woody debris, undercut banks, submerged root mats and leaf packs.

Plates E1 & E2: Photos of the Nile River at the 'Glen Mavis' site, showing the mixture of native and exotic vegetation that is found on the riverbank and floodplain. A typical shallow riffle, area of exposed cobble substrate and small pool (all of which occur during periods on low flow) are also shown.

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

2. Environmental Values and Objectives

Under the CFEV program, the reaches of the lower Nile River around 'Glen Mavis' have been assessed as having varying degrees of naturalness (i.e. 'low' to 'high') (CFEV 2005); however, this stretch of river has been classified as having a 'very high' conservation management priority[*]. According to the CFEV database the main values that appear to drive the conservation management priority for this part of the river relate to the terrestrial and riparian vegetation community through which it flows. There are also a number of special values that relate specifically to this aquatic ecosystem, namely:

- High priority riparian flora communities
- Lowland *Poa* grassland
- Shrubby *Eucalyptus ovata* forest
- Drooping sedge (*Carex longebrachiata*)
- Bitter cryptandra (*Cryptandra amara*)

In addition to these special values, other important biophysical classes are identified within the CFEV database. These relate to: (1) the fish assemblage that inhabits this area of the catchment, (2) freshwater crayfish that occur within the region, (3) the unique aquatic plant communities that occur in the lower Nile River, (4) aquatic macroinvertebrate* communities, and (5) the geomorphology of the river. All of the information that was obtained from the CFEV database and used to develop environmental objectives for this study, is presented and discussed within the broader context of the South Esk catchment in Chapter 2 of the main report.

In summary, an environmental flow for the lower Nile River should aim to provide sufficient water to meet the needs of:

- the fish community occurring in the river (particularly native species such as blackfish),
- endemic freshwater crayfish (*Astacopsis franklinii*),
- platypus (*Ornithorynchus anatinus*),
- aquatic and riparian plant communities within the river corridor,
- aquatic macroinvertebrate communities,
- riverine productivity and basic foodweb structure, and
- fluvial geomorphic processes.

Based on this information, Table E1 presents the main objectives that an environmental flow regime should address and the flow components that are required

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

to achieve these objectives. Further information about these flow components, and aspects of 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.

Table E1: The environmental objectives of the environmental flow assessment for the lower Nile River, and important components of the flow regime that support the objectives.

Environmental objectives for the Nile River	Flow components that are important* in maintaining the environmental objectives, and their scientific basis
Maintain healthy populations of native fish	• Seasonal occurrence and magnitude of freshes and minor flood events that act as triggers for migration and dispersal • Baseflows that provide riverine connectivity during summer • 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 mechanisms of 'drift' and dispersal. • Bankfull and overbank flows during winter and spring to maintain riparian vegetation as sites for breeding and oviposition, and source of instream wood and leaf-packs for food and habitat • Minimum flows to support adequate instream habitat and maintain wetted leaf-packs during dry months
Provide habitat of good quality for instream biota	• 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 fine sediments from riffle macropores • Minimise the duration of extreme low-flow events that may impact on the habitat of endemic freshwater mussels
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 biofilms
Maintain populations of platypus	• Summer low-flows and winter high flows for foraging and maintenance of leaf-packs • 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 stimulate re-generation through disturbance, disperse seeds and aid recruitment
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 floodplain features and processes

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

Table E1 clearly shows that environmental flow provisions for the lower Nile River should not simply focus on providing a 'minimum flow' during the dry months, but rather, they need to provide adequate water over 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 reach 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 Nile River at 'Glen Mavis' (summarised in Chapter 3 of the main report) shows that the combined impact of water use in the catchment has caused a substantial change to the low-flow component of the flow regime (~20% decline in mean daily flow during the summer months). Current water abstraction in the sub-catchment has not altered high flows. Subsequently, the following environmental flow assessment for the river focuses on providing information on what might constitute an environmentally appropriate minimum flow, as well as flood-flow provisions that are likely to maintain the identified environmental values. Given that the current level of water abstraction in this sub-region presently poses minimal risk to existing environmental values, the recommendations made in the following sections are aimed at preserving these values even if water use in this catchment increases in the future.

4. Minimum flow analysis

Chapter 5 of the main report details the methods used to conduct this assessment and the analytical approach used to derive the environmental flow recommendations. No prior work has been done to assess instream habitat in the lower Nile River. Therefore, a 'representative reach' of the river was selected at 'Glen Mavis' and surveyed in November 2006 to collect information on channel form and gradient. At the time of the survey, water depth and velocity profiles were measured and the discharge was calculated (0.24 $m^3.s^{-1}$ or 21 $ML.day^{-1}$). In addition, electrofishing was conducted to verify the composition of the fish assemblage inhabiting the river in this area. Blackfish (*Gadopsis marmoratus*) and brown trout (*Salmo trutta*) were the only species surveyed, but the short-finned eel (*Anguilla australis*) and *Galaxias* species. are also likely to occur in this region.

The minimum flow requirements for the lower Nile River site were assessed by using habitat preference information (i.e. depths and velocities) for fish species that were present (and those likely to occur in the region), general macroinvertebrate abundance, freshwater crayfish (*Astacopsis franklinii*) and platypus. 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 E1). This habitat-use curve includes the habitat preferences for adult and juvenile brown trout. Although brown trout are an introduced species, the inclusion of this species did not 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 curve for adult blackfish at this reach, which of all the fish species present has the highest priority in terms of conservation.

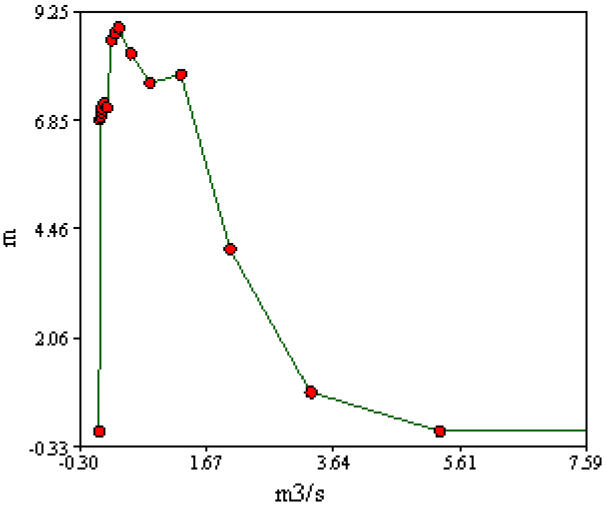

Figure E1: The 'mobile' fauna assemblage habitat-use curve for the Nile River at the 'Glen Mavis' site. This rating curve, which shows how habitat availability varies with changes in flow, is derived from the amalgamated information on habitat preferences for native and introduced fishes, crayfish and platypus.

The habitat-use curve for macroinvertebrate abundance (Figure E2) suggests that similar amounts of habitat are available for both the 'mobile' fauna and invertebrates (which are more benthic) in this reach (as indicated by the similar peak values on the y-axes; Figures E1 & E2). However, habitat for invertebrates is available over a much greater range of flows (0.2 to 14 $m^3.s^{-1}$; Figure E2). This assemblage is much less mobile and therefore more reliant on the habitat provided by substrates within the river channel. As a result, it is less affected by the greater water depths and higher velocities that occur during higher flows.

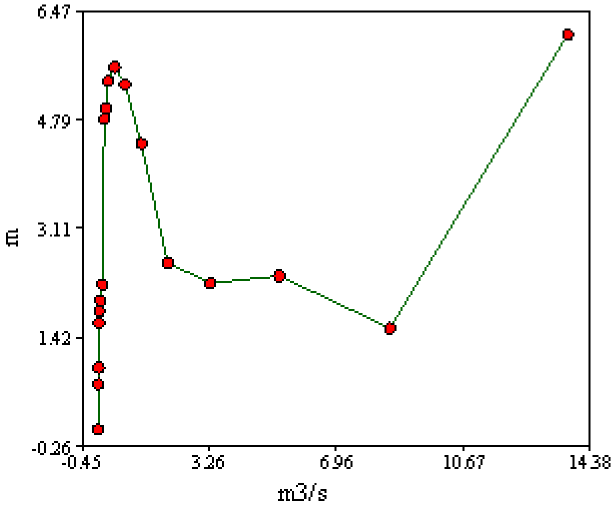

Figure E2: The general invertebrate abundance habitat-use curve for the Nile River at the 'Glen Mavis' site. This rating curve shows how habitat availability varies with changes in flow in this reach.

Due to this contrast in the habitat requirements of the two assemblages, each habitat-use curves (Figures E1 & E2) was used separately to examine minimum flows and consequently develop environmental flow recommendations.

The habitat-use curve for 'mobile' fauna (Figure E1) shows that flows between 0.1 and 2.0 $m^3.s^{-1}$ (9 and 173 $ML.day^{-1}$) provide optimal conditions for this assemblage at the Nile site. The maximum amount of habitat available for this assemblage is 8.9 m^2 per metre of river length and this occurs when flow is about 0.32 $m^3.s^{-1}$ (28 $ML.day^{-1}$). These findings are supported by the known habitat preferences of adult blackfish: they use pools where there is cover provided by snags and low water velocities. Flows between 0.1 and 2.0 $m^3.s^{-1}$ would allow pools to have depths and velocities that provide optimal conditions for habitation by these fish. Higher flows are likely to 'wash-out' these habitats and force the fish to seek refuge in other non-preferred habitats.

Conversely, the habitat-use curve for invertebrate abundance (Figure E2) shows that flows between 0.2 and 13.7 $m^3.s^{-1}$ (17 and 1184 $ML.day^{-1}$) provide optimal conditions (>1.5 m^2 per metre of river length) for this assemblage at the Nile site. The maximum amount of habitat available for this assemblage is 6.1 m^2 per metre of river length and this occurs when flow is at 13.7 $m^3.s^{-1}$ (1,184 $ML.day^{-1}$). The benthic assemblage prefers higher flows and can withstand flows of a much greater range than the mobile assemblage.

The faunal rating curves for the 'Glen Mavis' study site can be used to convert the time series of 'natural' streamflow at the catchment outlet (from the hydrological model for the catchment) into a time series of habitat availability for each assemblage. However, because this component of the assessment is focussed on the low-flow aspect of the water regime, a procedure known as 'baseflow separation' was performed (using the Lyn-Hollick filter for digital baseflow separation, with an alpha-value of 0.94). For this study, 43 years of daily average flow data was used as this is the period that has the best record of rainfall and evaporation data on which predictions of flow can be made. The resulting baseflow time series (see Figure E3) reflects the changes in the underlying baseflow and removes the much more variable surface flows caused by runoff which are less relevant to the derivation of minimum flows.

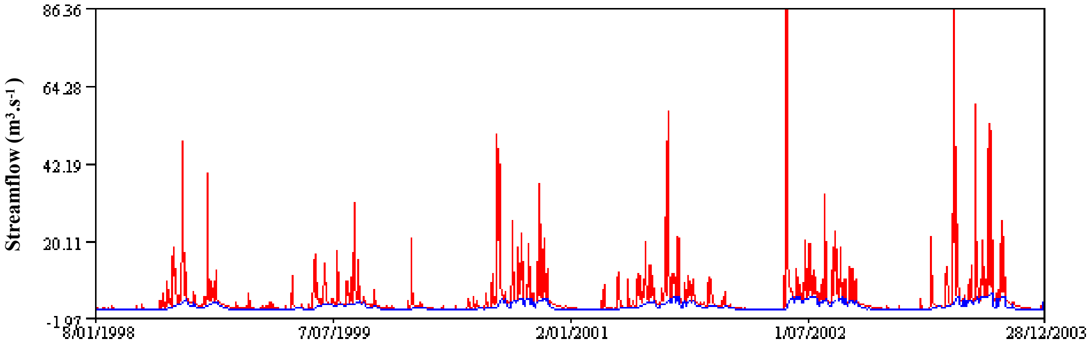

Figure E3: Time series of modelled 'natural' flow (red) and baseflow (blue) for the Nile River at 'Glen Mavis' between January 1998 and December 2003. Baseflow separation from the modelled 'natural' flow was performed using the Lyn-Hollick filter for digital baseflow separation, with an alpha-value of 0.94. Note this is only a sample of the full time series that extends from January 1960 to December 2003.

The baseflow time series that was generated (Figure E4) was then used to generate a time series of changes in available habitat within the river using the habitat rating curves (Figures E1 & E2). It is clear from the habitat-availability time series for the 'mobile' fauna (orange line in Figure E4) that higher flows create unfavourable conditions and decrease the availability of preferred habitats for this assemblage (i.e. there is an nearly an inverse relationship between the changes in baseflows and habitat availability). The habitat-availability time series for this assemblage implies that habitat availability falls to zero at times of high flow (i.e. during winter and spring). However, during these periods the taxa included in this curve will actually seek refuge in low-velocity areas such as within snag piles, behind large boulders and, for crayfish and platypus, in the banks of the river. Thus, while 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 suitable condition.

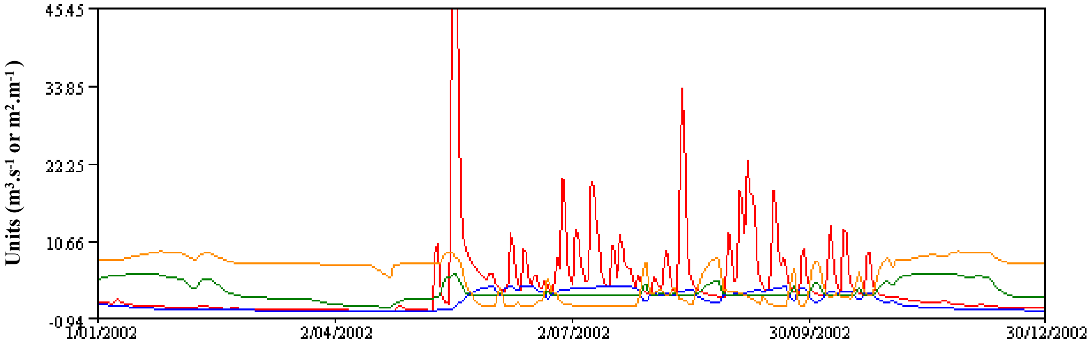

Figure E4: Time series of modelled 'natural' flow (red) and baseflow (blue) for the Nile River at 'Glen Mavis', along with modelled changes in habitat availability for 'mobile' fauna (orange) and general invertebrate abundance (green) between January and December 2002. Flow is shown in cumecs (m^3.s^{-1}) and habitat availability is shown in square metres per metre of river length (m^2 m^{-1}). 'Mobile' fauna includes native and introduced fishes, freshwater crayfish and platypus. Note this is only a sample of the full time series that extends from January 1960 to December 2003.

In contrast, the habitat-availability time series for the 'benthic' fauna (green line in Figure E4) shows that habitat for invertebrates remains relatively more available despite variability in flows. Thus, a range of flows provide favourable conditions, including access to preferred habitats, for this assemblage. However, the amount of modelled habitat within this section of the river diminishes (i.e. approaches zero) when flows fall below 0.2 $m^3.s^{-1}$ (17 $ML.day^{-1}$). When flow falls to this level, the amount of suitable habitat for invertebrates inhabiting the bed of the river is greatly reduced.

The habitat availability time series data for each assemblage can be transformed and used to examine the relationship between flows and the average amount of habitat available on a monthly basis (Figure E5). Habitat availability for each assemblage varies seasonally (Figure E5), although this is more pronounced for the 'mobile' assemblage (as previously mentioned in relation to seasonal variability in flow). During most seasons (spanning October-June), when average monthly flows are 0.6-5.4 $m^3.s^{-1}$ (52 to 467 $ML.day^{-1}$), >60% of preferred habitat is available for the 'mobile' fauna assemblage. However, during July-September, when average monthly flows are 6.1-9.7 $m^3.s^{-1}$ (527 to 838 $ML.day^{-1}$), the availability of preferred habitats is very limited for this assemblage (<60% of preferred habitat is available). Whilst habitat availability remains relatively more consistent for invertebrate abundance, ≤50% of preferred habitat is available for this assemblage during February, March and August. These temporal restrictions in habitat availability are due to low flows in the summer months (average monthly flows: 0.6 and 0.7 $m^3.s^{-1}$ in February and March respectively) and high flows in winter (average monthly flows in August = 9.7 $m^3.s^{-1}$ or 838 $ML.day^{-1}$).

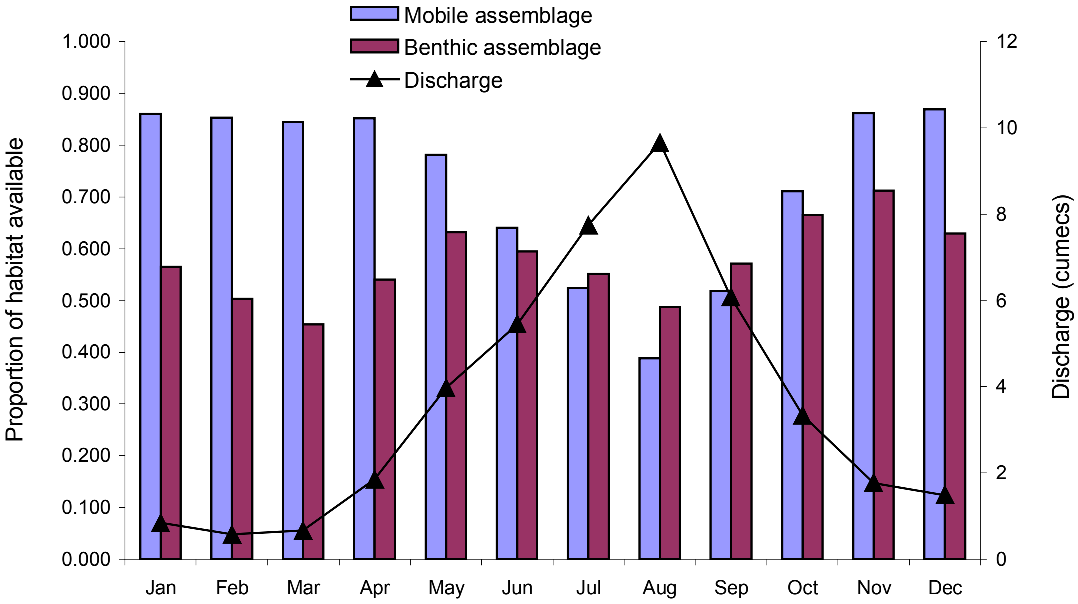

Figure E5: The average proportion of preferred habitat available for the 'mobile' fauna assemblage (blue bars) and general invertebrate abundance (red bars) and monthly average 'natural' flow (black line) in the Nile River at 'Glen Mavis'. The proportion of habitat available is a function of temporal availability relative to the maximum area this is available at the optimal flows for each assemblage.

Clearly, during the 'dry' months of November to April, when monthly average flows are <2 $m^3.s^{-1}$ (173 $ML.day^{-1}$) and average baseflows are <0.7 $m^3.s^{-1}$ (60 $ML.day^{-1}$), it is the benthic fauna that is at greatest risk of being affected by reduced flows. Therefore, it is appropriate that during these months the minimum flow recommendations are aimed at providing adequate habitat for the 'benthic' fauna assemblage.

To assist in determining a minimum flow level, the time series of habitat area available for benthic fauna that was derived from the 43-year modelled record of 'natural' baseflows was statistically analysed. The daily data for each month were aggregated and from these subsets, percentiles of habitat availability were calculated (Figure E6). Figure E6 shows the monthly change in selected percentiles of habitat area available for general invertebrate abundance at the study reach at 'Glen Mavis'. During January-April, the 50th percentile of habitat area available is <3.5 $m^2.m^{-1}$, which is about one third of the total surface area of the river under average flows that occur during that period.

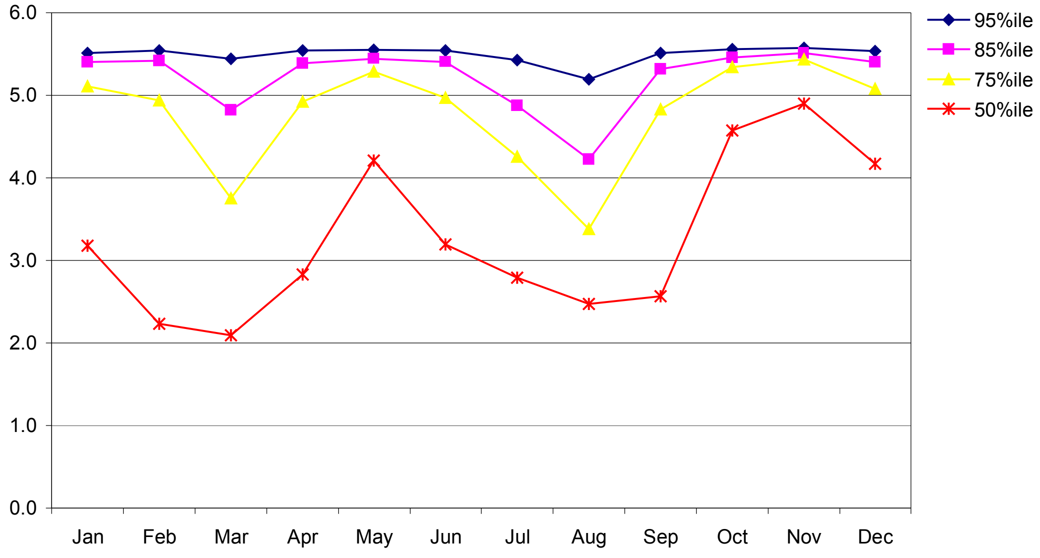

Figure E6: Percentiles of habitat area available for general invertebrate abundance in the Nile River at 'Glen Mavis' using modelled 'natural' baseflows from 1960 to 2003.

Table D2 provides an indication of the flows (as a daily averages) which provide vary amounts of habitat for the benthic fauna assemblage in the lower Nile River. 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. In developing a minimum flow recommendation for the lower Nile River, some consideration should also be made to maintaining connectivity between pools during dry periods. As well as maintaining connectivity, the other potential issue in this area is wetting of leaf-packs within the channel, which provide both habitat and food for a variety of aquatic organisms (Lancaster & Hildrew, 1993). For this reach, an examination was made of the transect data from the hydraulic model. This indicated that connectivity between pools and wetting of leaf-packs is maintained during very low flows (<0.01 $m^3.s^{-1}$), and is therefore not an issue that requires further attention during this assessment.

Table E2: Monthly 85th, 75th and 50th percentiles of instream habitat for 'benthic fauna' derived from 'natural' baseflow data, and the corresponding flows that 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	5.40	0.32	5.10	0.27	3.17	0.20
Feb	5.41	0.32	4.94	0.22	2.23	0.10
Mar	4.82	0.21	3.75	0.22	2.10	0.10
Apr	5.39	0.32	4.92	0.27	2.83	0.21
May	5.44	0.43	5.28	0.32	4.21	0.21
Jun	5.40	0.32	4.96	0.27	3.19	0.21
Jul	4.87	0.27	4.26	0.22	2.79	0.21
Aug	4.22	0.21	3.38	0.27	2.47	0.21
Sep	5.32	0.33	4.82	0.27	2.57	0.15
Oct	5.46	0.38	5.34	0.31	4.57	0.21
Nov	5.51	0.49	5.43	0.38	4.90	0.26
Dec	5.40	0.32	5.08	0.32	4.16	0.26

4.1 Recommendations for minimum flow provisions

Although the data provided in Table E2 provides useful information on 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 ecological consequences.

The 'habitat availability' values in Table D2 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, and is most likely to maintain a healthy community of macoinvertebrate fauna and fish. 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.

When the monthly 50% habitat maintenance flows (which range between 0.1-0.26 $m^3.s^{-1}$) are considered with respect to the rating curves for each of the assemblages (Figures E1 and E2), it would appear that for both faunal communities there is likely to be an increased risk that insufficient habitat is maintained. As mentioned above, pool connectivity is not an issue, as even at very low flows (<0.01 $m^3.s^{-1}$) the size of the substrate allows considerable seepage of water between pools. Examination of the natural flow time-series shows that these extremely low flows conditions are usually brief. During these times benthic organisms are able to find refuge in the bed of the river and fish will take refuge in the deeper pools and snag piles where these are available.

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

On this basis, it is recommended that an environmental flow for the lower Nile River should maintain 75% of instream habitat for aquatic invertebrate fauna, and that 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 a suitable 'cease-to-take' flow. The monthly flows that correspond to these levels are provided in Table E3.

The main focus of this recommendation is on the provision of minimum flows during the irrigation season (October to April) when the extraction of water directly from the river is of greatest concern and is most actively managed. During the months outside of this period, water allocation is currently focussed on the capture of floodwater for on-farm storage, so the minimum flow values for these months may not apply but are provided nevertheless.

Table E3: Recommended environmental flows and 'cease-to-take' flows for the lower Nile River at Glen Mavis.

MONTH	Environmental flow (75% of habitat maintenance flow) ($m^3.s^{-1}$)	Cease-to-take flow (50% habitat maintenance flow) ($m^3.s^{-1}$)
Jan	0.27	0.20
Feb	0.22	0.10
Mar	0.22	0.10
Apr	0.27	0.21
May	0.32	0.21
Jun	0.27	0.21
Jul	0.22	0.21
Aug	0.27	0.21
Sep	0.27	0.15
Oct	0.31	0.21
Nov	0.38	0.26
Dec	0.32	0.26

5. Flood flow analysis

In contrast to low flows, 'flood flows' or 'high flows' comprise the majority of the complexity and variability in the flow regime of a river. Flow events that characterise 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 we all 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 the variety of hydraulic environments that supports instream flora and fauna (see discussion in Biggs *et. al*., 2005; and 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. Bank-full discharge is one useful threshold for analysis as it is often assumed to control the form of alluvial channels (Gordon, *et. al,* 2004), and is considered to have an important role in 'channel maintenance' and the transport of sediment (Newbury and Gaboury, 1993; Gippel, 2001).

High spells analysis was conducted for the study reach on the lower Nile River using the 20% exceedance* (4.3 $m^3.s^{-1}$ or 372 $ML.day^{-1}$), 10% exceedance (9.0 $m^3.s^{-1}$or 778 $ML.day^{-1}$) and 5% exceedance (16 $m^3.s^{-1}$ or 1,380 $ML.day^{-1}$) flows as thresholds (Table E4). Based on the pattern of rise and fall in the hydrograph for the lower Nile River, high spell events were defined as those that last for ≥1 day and were calssified as independent if there were at least 5 days between the peaks in associated flow events. Natural flow data from the hydrologic model for the South Esk catchment were used as input in these analyses; data from this model are at a daily time-step as 'daily average flow'.

The 20% exceedance threshold was used to examine the seasonal frequency and duration of smaller events that could be classified as 'freshes' or 'flushing' flows. The 10% exceedance flow threshold represents discharges when water level is estimated to fill the river channel; this was determined visually from the hydraulic model for the reach. At flows of this magnitude, bank erosion and sediment transport processes are likely to occur (average water velocity in-channel exceeds 0.5 $m.s^{-1}$), hence, this can be considered as being roughly equivalent to a 'channel maintenance' flow. The 5% exceedance flow represents larger events when water inundates riparian areas and flood terraces.

Over the 43 years of record, 10% exceedance events have occurred on average about 6 times per year, have an average duration of about 6 days, and an average magnitude of 30 $m^3.s^{-1}$ (Table E4). The majority of the high spells have occurred between May and October, with very few occurring in summer and early autumn. Irrespective of when high spells occur, they generally cause varying degrees of over-bank flooding as the average magnitudes for event thresholds are in the range at which water levels exceed full bank levels at this reach (15-25 $m^3.s^{-1}$). Furthermore, when high spells occur, they generally tend to last for between 3 and 7 days, with those occurring in winter lasting longer than events that occur in the other seasons.

The data in Table E5 shows the average duration and rates of rise and fall in the hydrograph for the river at the 'Glen Mavis' study reach. It provides additional information on rates of change in flow that occur, and illustrates that the river responds rapidly to runoff. Whilst these figures are informative, they are most valuable when viewed in conjunction with figures derived for other locations in the river system. It must also be remembered that they have been derived using *daily* time series data, which is the shortest time-step available from the hydrological model for the catchment.

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

Table E4: Summary of ‘high spells’ analysis using ‘natural’ flow data for the lower Nile River at ‘Glen Mavis’. The 20% exceedance threshold (4.3 $m^3.s^{-1}$) approximates minor ‘freshes’ or ‘flushing’ events at this reach, The 10% exceedance threshold (9.0 cumecs) approximates ‘bank-full’ discharge, and the 5% exceedance threshold (16 cumecs) approximates flows that inundate riparian areas and floodplain terraces.

	20% exceedence (4.3 $m^3.s^{-1}$ or 372 $ML.day^{-1}$)			**10% exceedence (9.0 $m^3.s^{-1}$ or 778 $ML.day^{-1}$)**			**5% exceedence (16 $m^3.s^{-1}$ or 1,380 $ML.day^{-1}$)**		
	Average frequency	Average duration (days)	Average magnitude ($m^3.s^{-1}$)	Average frequency	Average duration (days)	Average magnitude ($m^3.s^{-1}$)	Average frequency	Average duration (days)	Average magnitude ($m^3.s^{-1}$)
Annual	12.2	6.1	20.5	6.2	5.9	30.4	4.7	3.7	38.3
Spring	3.4	5.4	18.1	1.7	4.9	22.4	1.2	3.2	32.3
Summer	0.6	3.8	14.7	0.3	4.3	31.9	0.2	2.5	27.9
Autumn	2.0	5.0	23.2	1.1	4.4	35.1	0.5	3.6	46.7
Winter	6.3	7.0	23.2	3.3	7.2	30.4	2.8	3.8	38.4

Table E5: Average duration of rise and fall in flow, and rates of change in flow for the Nile River at ‘Glen Mavis’.

Statistic (Using Whole of record)	**Nile River at ‘Glen Mavis’**
Mean duration of Rises (days)	2.12
Mean rate of Rise ($ML.day^{-1}$)	3.8
Mean duration of Falls (days)	8.4
Mean rate of Fall ($ML.day^{-1}$)	1.9

Tables E4 and E5 show the average seasonal distribution, size, duration and rates of change of ecosystem-relevant flow pulses, but flows may also vary between years. Figure E7 illustrates inter-annual variations in hydrographs for the years 1995 and 1996, along with the 10% exceedance flow threshold. This figure highlights the substantial variations between years in the frequency and magnitude of these events. In 1995, four events exceeded the threshold during late autumn – early spring. These events did not last long and were comprised of flows <30 $m^3.s^{-1}$. Conversely, in 1996 the threshold was also exceeded four times, but these events occurred during late winter-spring and two of these events had flows of >40 $m^3.s^{-1}$.

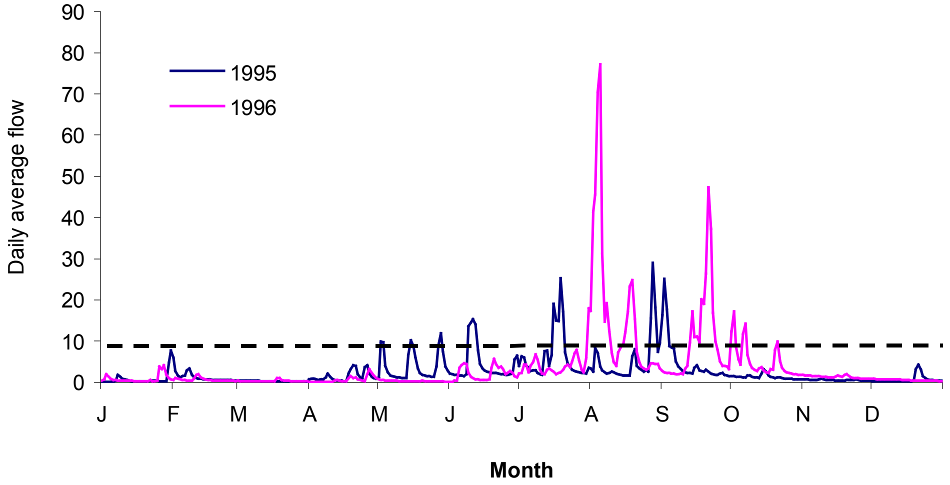

Figure E7: Comparison of daily average 'natural' flow of the Nile River during 1995 (blue line) and 1996 (pink line). The 10% exceedance flow threshold (9.0 $m^3.s^{-1}$; which represents 'channel maintenance' flows) is also indicated (horizontal dashed line).

Figure E7 highlights the hydrologic variability of the lower reaches of the Nile River. To preserve this variability care must be taken when developing rules to manage extraction of water from this part of the flow regime.

In making recommendations regarding the extraction of water from medium to large flow events, it is important that, where practical, the natural pattern of flow variability be maintained. This is the main premise of the Tasmanian Environmental Flows Framework (TEFF), which the DPIW supports. 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. As the data from 1995 clearly illustrates (Figure E7), in the absence of significant rainfall events, it is the smaller flow 'pulses' that provide the main structure to the flow regime and, therefore, it is these that must be preserved. As mentioned above, when channel maintenance flows do occur, on average, they tend to greatly exceed the bank-full threshold, providing excess water to the floodplain. In this reach, this water will help maintain native riparian vegetation communities; however, it also a component of the flow regime from which managed extractions may have least affect on the health of the river's ecosystem. Bearing this in mind, the following recommendation is made.

5.2 Recommendations for allocation of flood water

It is recommended that the allocation of floodwater be restricted to times when flow at this reach exceeds 9.0 $m^3.s^{-1}$ (780 $ML.day^{-1}$). Extraction of flood-water at this time should not be allowed to significantly affect flood duration, and to ensure this, it is recommended that 150 $ML.day^{-1}$ be made available for extraction for up to 4 days once 9.0 $m^3.s^{-1}$ is exceeded or until flow falls below this threshold. This volume of water represents about one fifth of the 10% exceedance 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 9 $m^3.s^{-1}$ occur on average about 6 times per year, this makes approximately 3,600 ML potentially available on an annual basis. No seasonal boundaries to this rule are proposed.

Under the recommended flood allocation rules outlined above, all flow events occurring below the 9 $m^3.s^{-1}$ flow threshold are protected. The ecological value of these smaller events is particularly important during prolonged periods of low-flow. Such events provide some variability when conditions have been static, and have been viewed as having a role in 'relieving stress' on the system (Poff, *et al.*, 1997), mainly through the mechanism of ameliorating water quality (Webster, *et al.*, 2000). In a dry year these events may constitute a large proportion of the variability in the water regime, and it is these events that are most impacted by the proliferation of catchment dams. For all rivers in the South Esk catchment, these events are presently provided some measure of protection by the flood harvesting rules 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 be recognised that the recommendations made here need to be considered in the light of similar recommendations made for locations elsewhere in the South Esk River system. Any water that is allocated at this point needs to be accounted for in downstream management and as part of an overall 'extraction cap' for the catchment.

6. Summary

Like many other parts of the South Esk system, the environmental values that have been identified for the Nile River relate primarily to the high priority riparian and floodplain plant communities, highly valued aquatic fauna and fish, and the geomorphic character and processes that maintain instream habitat and productivity. In providing environmental flows to maintain these values, the objective has primarily been to retain as much as possible the natural variability in the flow regime. To do this, recommendations have been made regarding monthly minimum flow provisions and extraction rules aimed at preserving the pattern and shape of the high flow components of the flow regime.

Monthly minimum flows have been recommended with the aim of maintaining sufficient habitat to sustain benthic macroinvertebrate abundance and the fish community, and 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 sub-catchment level. 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 'winter' allocation of water.

Basic rules have been recommended regarding the extraction of water during times of flood, and these need to be considered in tandem 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 Nile River and sustain the ecosystem into the future.